State of California
The Resources Agency
Department of Water Resources

FINAL REPORT
EVALUATION OF THE TIMING, MAGNITUDE AND FREQUENCY OF WATER TEMPERATURES AND THEIR EFFECTS ON CHINOOK SALMON EGG AND ALEVIN SURVIVAL
SP-F10, TASK 2C

Oroville Facilities Relicensing
FERC Project No. 2100

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REPORT SUMMARY

The original objective of Task 2C of Study Plan (SP) F10 was to evaluate the timing, magnitude, and frequency of water temperatures and their effects on the distribution of salmonid spawning and on egg and alevin survival in the lower Feather River from the Fish Barrier Dam downstream to its confluence with the Sacramento River. Because the purpose of Task 2B was re-scoped to evaluate the effects of Oroville Facilities operations on spawning Chinook salmon in the lower Feather River, accordingly the purpose of Task 2C was re-scoped to evaluate the effects of Oroville Facilities operations on Chinook salmon egg and alevin survival in the lower Feather River. Evaluation of operational effects was emphasized because operation of the Oroville Facilities affects water temperatures in the Feather River, which in turn influences egg and alevin water temperature-induced mortality. The results of this study will provide information regarding Chinook salmon egg and alevin losses due to water temperature-induced mortality in the lower Feather River under current operations. Additionally, the results of this study could be used to evaluate future potential Resource Actions involving water temperature changes and their potential effects on Chinook salmon egg and alevin mortality.

To complete Task 2C of SP-F10, SWRI modified the USBR Chinook salmon water temperature mortality model by updating spawning and pre-spawning distributions, and mean daily water temperature series. Cumulative Chinook salmon carcass distributions were smoothed to provide continuous spawning and pre-spawning distributions of Chinook salmon in the lower Feather River. Because of gaps in water temperature data collected by the monitoring loggers, spatial models of water temperature and river reach were used to estimate continuous series of average mean daily water temperature for each of the nine reaches used in the USBR Chinook water temperature mortality model. Upon completion of the spawning and pre-spawning distributions, and continuous water temperature data series, modeling was conducted to determine percentages of Chinook salmon egg and alevin losses due to water temperature-induced mortality in the lower Feather River.

The analysis for SP-F10 Task 2C indicates that Chinook salmon egg and alevin losses during the 2002/2003 spawning and incubation season in the lower Feather River was 16.3 percent, with 10.6 percent occurring in the Low Flow Channel (LFC) and 5.7 percent occurring in the High Flow Channel (HFC). Early life stage water temperature-induced mortalities were estimated for various runs of Chinook salmon in the recent BA conducted for the CVP and SWP OCAP using the USBR model (USBR 2004). In the OCAP BA, early life stage mortalities were estimated for fall-run and spring-run Chinook salmon in the Sacramento River, and for fall-run Chinook salmon in the lower American River, rivers proximate to the lower Feather River. Results of this study (SP-F10 Task 2C) were compared to the OCAP BA early life stage mortality estimates for general comparative purposes. In the OCAP BA the long-term average mortality rate for fall-run Chinook salmon under existing conditions was estimated to be 14.5 percent in the lower American River. Furthermore, in the Sacramento River, the long-term average mortality

rate for fall-run Chinook salmon was estimated to be 13.2 percent, and spring-run Chinook salmon mortality was estimated to be 20.8 percent at Balls Ferry, and 26.5 percent at Bend Bridge and Jelly's Ferry.

The 16.3 percent Chinook salmon early life stage mortality rate estimated in this report for the lower Feather River is within the range of the recent estimates in the OCAP BA (USBR 2004) for spring-run and fall-run Chinook salmon in the Sacramento River, and fall-run Chinook salmon in the lower American River.

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1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Ongoing operation of the Oroville Facilities influence water temperature in the Feather River downstream of the Thermalito Diversion Dam. Water temperature is an important factor influencing the Chinook salmon egg and alevin survival. As a component of study plan (SP)-F10, Evaluation of Project Effects on Salmonids and their Habitat in the Feather River Below the Fish Barrier Dam, Task 2 of SP-10 evaluates project effects on the spawning and incubation period of salmonids in the lower Feather River. The original objective of Task 2C of Study Plan (SP) F10 was to evaluate the timing, magnitude, and frequency of water temperatures and their effects on the distribution of salmonid spawning and on egg and alevin survival in the lower Feather River from the Fish Barrier Dam downstream to confluence with the Sacramento River. Because the purpose of Task 2B was re-scoped to evaluate the effects of Oroville Facilities operations on spawning Chinook salmon in the lower Feather River, accordingly the purpose of Task 2C was re-scoped to evaluate the effects of Oroville Facilities operations on Chinook salmon egg and alevin survival in the lower Feather River. Task 2C, herein, evaluates the timing, magnitude and frequency of water temperatures and their effects on Chinook salmon egg and alevin survival in the lower Feather River.

1.1.1 Statutory/Regulatory Requirements

The purpose of SP-F10 Task 2C is to evaluate the timing, magnitude and frequency of water temperatures and their effects on Chinook salmon egg and alevin survival in the lower Feather River. Salmonids present in the lower Feather River include spring-run Chinook salmon (*Oncorhynchus tshawytscha*), fall-run Chinook salmon (*O. tshawytscha*), and steelhead (*O. mykiss*). On September 16, 1999, naturally-spawned Central Valley spring-run Chinook salmon were listed as threatened under the federal Endangered Species Act (ESA) by the Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NOAA Fisheries) (NOAA Fisheries 1999). The Central Valley spring-run Chinook salmon Evolutionarily Significant Unit (ESU) includes all naturally-spawned populations of spring-run Chinook salmon in the Sacramento River and its tributaries, which includes naturally-spawned spring-run Chinook salmon in the lower Feather River (NOAA Fisheries 1999). On March 19, 1998, naturally-spawned Central Valley steelhead were listed as threatened under the federal ESA by NOAA Fisheries (NOAA Fisheries 1998). The Central Valley steelhead ESU includes all naturally-spawned populations of steelhead in the Sacramento and San Joaquin rivers and their tributaries, which includes naturally-spawned steelhead in the lower Feather River (NOAA Fisheries 1998).

The results and recommendations from this study fulfill, in part, statutory and regulatory requirements mandated by the ESA as it pertains to Central Valley spring-run and fall-run Chinook salmon. In addition to the ESA and California Species of Special Concern, Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects, including a discussion of the fish, wildlife, and botanical resources in the vicinity of the project (FERC 2001). The discussion is required to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact for on-going and future operations. As a subtask of SP-F10, Task 2C fulfills a portion of the FERC application requirements by detailing the effects of water temperatures on Chinook salmon egg and alevin survival in the lower Feather River. In addition to fulfilling these requirements, information collected during this task may be used in developing or evaluating potential Resource Actions.

1.1.2 Study Area

The study area for Task 2C of SP-F10 extends from the Fish Barrier Dam to the confluence of the Feather and Sacramento rivers. The study area in which the USBR Chinook salmon water temperature mortality modeling results of Task 2C of SP-F10 specifically apply to the upstream extent of the study area for this evaluation is the Fish Barrier Dam at river mile (RM) 67.25, and the downstream extent of the study area is the confluence of the Feather and Sacramento rivers at RM 0. The majority of spawning habitat available in the lower Feather River is located in this stretch of river. Two distinct reaches exist within the study area: the upstream reach, and the downstream reach. The upstream reach extends from the Fish Barrier Dam downstream to the Thermalito Afterbay Outlet (RM 59), and is referred to as the LFC. The downstream reach extends from the Thermalito Afterbay Outlet downstream to the confluence with the Sacramento River (RM 0), and is referred to as the HFC.

This geographic range within the Feather River encompasses the area potentially used as spawning habitat by adult spring-run Chinook salmon in the Feather River. The reach of the study area from the Thermalito Diversion Dam to the Fish Barrier Dam consists of the Fish Barrier Pool. The reach of the Feather River extending from the Fish Barrier Dam to the Sacramento River is composed of two operationally distinct segments. The upstream segment extends from the Fish Barrier Dam at RM 67.25 to the Thermalito Afterbay Outlet (RM 59), while the downstream segment extends from the Thermalito Afterbay Outlet (RM 59) to the confluence of the Feather and Sacramento Rivers (RM 0). The flow and water temperature regimes associated with each of these segments are distinct, and are summarized below.

Minimum flows in the lower Feather River were established in the August 1983 agreement between the California Department of Water Resources (DWR) and the California Department of Fish and Game (DFG) (DWR 1983). The agreement specifies that DWR release a minimum of 600 cubic feet per second (cfs) into the Feather River from the Thermalito Diversion Dam for fisheries purposes.

Therefore, the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet is operated at 600 cfs year round, with variations in flow occurring infrequently. Most flow deviations from 600 cfs occur during flood control releases, or in the summer in order to meet downstream temperature requirements for salmonids, or for maintenance or monitoring purposes. Because this reach of the Feather River is supplied directly by water taken from Lake Oroville's hypolimnion that is selected in order to meet Feather River Hatchery and other downstream water temperature requirements, water temperatures in this reach of the Feather River are typically lower than temperatures in the downstream reaches.

Unlike the constant flow regime in the upstream segment of the Feather River, the flow regime in the reach of the Feather River extending from the Thermalito Afterbay Outlet (RM 59) to the confluence of the Feather and Sacramento rivers (RM 0) varies depending on runoff and month. Minimum flow requirement in this reach of the Feather River range from 1,000 to 1,700 cfs, depending upon the percentage of normal runoff and the month. Although the minimum flow requirements range from 1,000 to 1,700 cfs, flow in the reach of the Feather River extending from the Thermalito Afterbay Outlet to the confluence of the Feather and Sacramento rivers typically ranges from the minimum flow requirement up to 7,500 cfs (DWR 1982). Flow in this reach is, therefore, more highly varied than flow in the upstream segment. Flow in the downstream segment is additionally influenced by small flow contributions from Honcut Creek (RM 44) and the Bear River (RM 13), and by larger flow contributions from the Yuba River (RM 29). Water temperature in the reach of the Feather River extending from the Thermalito Afterbay Outlet to the confluence with the Sacramento River is typically warmer than water temperature in the upper reaches of the Feather River. Water temperature in this lower reach is directly influenced by the water releases from the Thermalito Afterbay Outlet. Because the Thermalito Afterbay is a large, shallow, warming basin, water that is released from the Thermalito Afterbay Outlet is typically warmer than the water originating from the upstream reach of the main channel of the Feather River. Typically, the contribution to the total flow in the Feather River from the Thermalito Afterbay Outlet is generally greater than flow contribution from the upper reach of the Feather River, and water temperatures in the river downstream of the Thermalito Afterbay Outlet are generally warmer than water temperatures in the reach upstream of the Thermalito Afterbay Outlet.

1.1.2.1 Description

Flow requirements for the lower Feather River were determined by the August 26, 1983 agreement between the Department of Water Resources (DWR) and California Department of Fish and Game (DFG) titled "*Agreement Concerning the Operation of the Oroville Division of State Water Project for Management of Fish & Wildlife.*" This agreement states that a flow of 600 cfs is to be released into the main channel of the lower Feather River from the Thermalito Diversion Dam (i.e. diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline) for fishery purposes. In the reach of the lower Feather River downstream of the Thermalito Afterbay Outlet, water flow is supplemented by releases from the Thermalito Afterbay Outlet to maintain a minimum flow downstream to the mouth of the Feather River. During the month of September, the flow requirement in the reach of the lower Feather River extending downstream from the Thermalito Afterbay Outlet is 1,000 cfs. During the months of October through February, the minimum flow requirements for this reach are 1,200 or 1,700 cfs, depending on the percentage of unimpaired runoff of the Feather River near Oroville from the preceding water year as compared to the normal unimpaired runoff of 1,942,000 acre-feet (mean of 1911-1960). Additionally, there is a requirement that specifies that if the highest average one hour flow of the combined project releases exceeds 2,500 cfs between October 15 and November 30, with the exception of releases for flood control, accidents, project failure, and major or unusual maintenance, then the minimum flow from October through March shall not be less than 500 cfs of the highest average one hour flow. The 2,500 cfs threshold was envisioned to protect redds in the event that spawning occurs in the overbank areas. From October through February, if flow is 1,700 cfs, then flow must remain at 1,700 cfs through March, and if flow is 1,200 cfs, then the flow requirement is 1,000 cfs in March. The project is usually operated such that only one major reduction in flow occurs downstream of Thermalito Afterbay Outlet during the months in which Chinook salmon are spawning and redds may be present in the lower Feather River (generally just before October 15).

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (maf) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

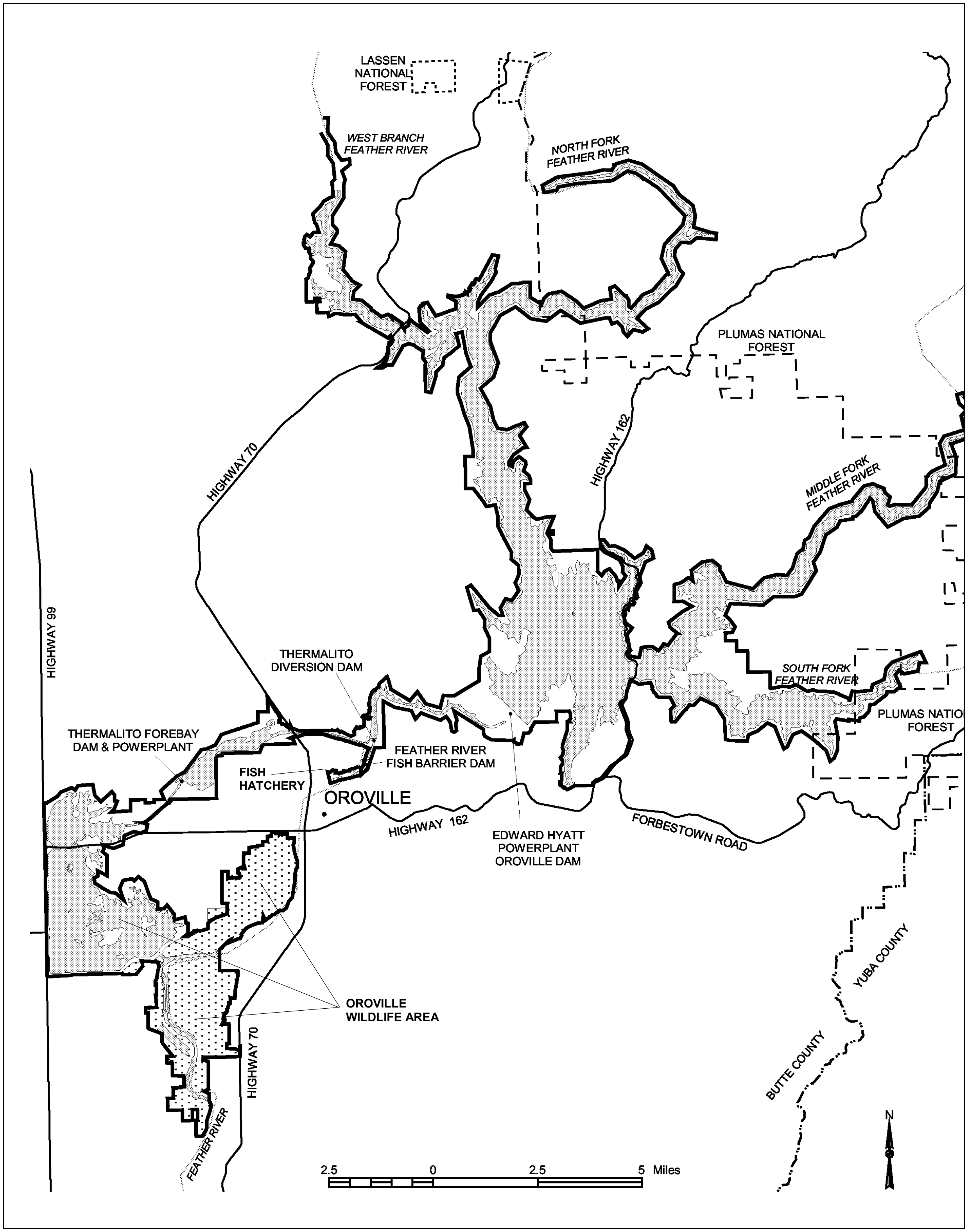

Figure 1.2-1. Oroville Facilities FERC Project Boundary.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate an average of 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. DFG's habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG entitled, "Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish

& Wildlife," sets criteria and objectives for flow and temperatures in the LFC and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the Lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Water Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for objectives, April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead trout and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook and steelhead as a reasonable and prudent measure; DWR is required to control water temperature at Feather River mile 61.6 (Robinson's Riffle in the low-flow channel) from June 1 through September 30. This measure requires water temperatures less than or equal to 65°F on a daily average. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 maf. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 maf to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

Task 2C is a subtask of SP-F10, *Evaluation of Project Effects on Salmonids and their Habitat in the Feather River below the Fish Barrier Dam*. Task 2C fulfills a portion of the FERC application requirements by evaluating the timing, magnitude and frequency of water temperatures and their effects on Chinook salmon egg and alevin survival in the lower Feather River. In addition to fulfilling statutory requirements, information collected during this task may be used in developing or evaluating potential Resource Actions.

The original objective of Task 2C of Study Plan (SP) F10 was to evaluate the timing, magnitude, and frequency of water temperatures and their effects on the distribution of salmonid spawning and on egg and alevin survival in the lower Feather River from the Fish Barrier Dam downstream to confluence with the Sacramento River. Because the purpose of Task 2B was re-scoped to evaluate the effects of Oroville Facilities operations on spawning Chinook salmon in the lower Feather River, accordingly the purpose of Task 2C was re-scoped to evaluate the effects of Oroville Facilities operations on Chinook salmon egg and alevin survival in the lower Feather River.

Performing this study is necessary, in part, because operations of the Oroville Facilities affect water temperatures in the lower Feather River. Additionally, performing this study is necessary because operations of the Oroville Facilities affect Feather River flows, water temperatures, and channel morphology below Oroville Dam in a manner that may affect fish habitat. Water temperatures resulting from operation of the Oroville Facilities affect the survival of Chinook salmon eggs and alevins below Oroville Dam.

Ongoing operations of the Oroville Facilities influence the survival of Chinook salmon eggs and alevins. SP-F10 is titled *Evaluation of Project Effects on Salmonids and their Habitat in the Feather River below the Fish Barrier Dam*. Task 2 of SP-10 evaluates project effects on the spawning and incubation period of salmonids in the lower Feather River. Task 2C, herein evaluates the timing, magnitude and frequency of water temperatures and their effects on Chinook salmon egg and alevin survival in the lower Feather River. Task 2A evaluates spawning and incubation substrate availability and suitability, Task 2B evaluates the effects of the timing, magnitude and frequency of flows on spawning distributions, and Task 2D evaluates the potential effects of flow fluctuations on Chinook salmon redd dewatering. For further description of Tasks 2A, 2B and 2D, see SP-F10 and associated interim and final reports.

3.0 STUDY OBJECTIVE

The objective of SP-F10 Task 2C is to evaluate the timing, magnitude and frequency of water temperatures and their effects on Chinook salmon egg and alevin survival in the lower Feather River.

3.1 APPLICATION OF STUDY INFORMATION

The purpose of SP-F10 Task 2C is to evaluate the timing, magnitude and frequency of water temperatures and their effects on Chinook salmon egg and alevin survival in the lower Feather River. The objective of Task 2C of Study Plan (SP) F10 is to evaluate the effects of Oroville Facilities operations on Chinook salmon egg and alevin survival in the lower Feather River. Information obtained in this study is associated with, and will be applied to, the following purposes and activities.

3.1.1 Department of Water Resources/Stakeholders

The information from this analysis will be used by DWR and the Environmental Work Group (EWG) to evaluate potential on-going effects of project operations by evaluating the effects of water temperatures on Chinook salmon egg and alevin survival in the lower Feather River during the 2002/2003 spawning and incubation season. Additionally, data collected in this task serves as a foundation for future evaluation and development of potential Resource Actions.

3.1.2 Other Studies

As a subtask of study plan SP-F10, *Evaluation of Project Effects on Salmonids and their Habitat in the Feather River below the Fish Barrier Dam,* Task 2 of SP-10 evaluates project effects on the spawning and incubation period of salmonids in the lower Feather River. Task 2C, herein evaluates the timing, magnitude and frequency of water temperatures and their effects on Chinook salmon egg and alevin survival in the lower Feather River. Task 2A evaluates spawning and incubation substrate availability and suitability, Task 2B evaluates the effects of the timing, magnitude and frequency of flows on spawning distributions, and Task 2D evaluates the potential effects of flow fluctuations on Chinook salmon redd dewatering. For further description of Tasks 2A, 2B and 2D, see SP-F10 and associated interim and final reports.

3.1.3 Environmental Documentation

In addition to Section 4.51(f)(3) of 18 CFR, which requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects (FERC 2001), it may be necessary to satisfy the requirements of the National Environmental Policy Act (NEPA) as well as the Endangered Species Act (ESA). Because FERC has the authority to grant an operating license to DWR for continued operation of the Oroville Facilities, discussion is required to identify the potential impacts of the project on many types of resources, including fish, wildlife, and botanical resources. In addition, NEPA requires discussion of any anticipated continuing impact from on-going and future operations. To satisfy NEPA and ESA, DWR is preparing a Preliminary Draft Environmental Assessment (PDEA) to attach to the FERC license application, which shall include information provided by this study plan report.

3.1.4 Settlement Agreement

In addition to statutory and regulatory requirements, SP-F10 Task 2C provides information which may be useful in the development of potential Resource Actions to be negotiated during the collaborative process. Additionally, information obtained from modeling analysis of the mortality of Chinook salmon eggs and alevins due to water temperatures in the lower Feather River could be used to identify operating procedures negotiated during the collaborative settlement process.

4.0 METHODOLOGY

4.1 STUDY DESIGN

In 1990, USBR developed the Chinook salmon water temperature mortality models for the Sacramento River utilizing biological assumptions from USFWS and DFG (USBR 1991). These models were later developed by the USBR for use on other major northern California rivers. While similar salmon water temperature mortality models exist for the upper Sacramento, Trinity, and lower American rivers, quantitative analysis of Oroville Facilities effects on Chinook salmon mortality focuses on the lower Feather River. The water temperature and salmon mortality models, including the USBR Chinook salmon water temperature mortality model for the lower Feather River, have been used in several recent and current studies including the Trinity River SEIS, Freeport Regional Water Project-EIR/EIS, South Delta Improvement Project - EIR/EIS, OCAP Studies, and the Shasta Dam Enlargement Study (pers. comm., Yaworsky 2004).

The USBR salmon water temperature mortality models for the Sacramento, Trinity, Feather, American and Stanislaus rivers are documented in numerous reports (USBR 1991, USBR 1993, USBR 1994, and USBR 2003a). This USBR salmon water temperature mortality model was modified by USBR prior to May 1999 and had been reviewed and accepted by DWR fisheries biologists in early 2003 as part of the OCAP process (pers. comm., Yaworsky 2004). SWRI received the USBR salmon water temperature mortality model for the Feather River in July 2003 from USBR. Modifications to the model were made by SWRI in March 2004 for *SP-F10 Task 2C: Evaluate the timing, magnitude and frequency of water temperatures and their effects on Chinook salmon egg and alevin survival*. A summary of the updated model including SWRI modifications is provided below.

<u>4.1.1 Description of the USBR Chinook Salmon Water Temperature Mortality Model</u>

In the USBR Chinook salmon water temperature mortality model, temperature-exposure mortality criteria for three life stages (pre-spawned eggs (i.e., eggs in adults), fertilized eggs (i.e., eggs in redds), and pre-emergent fry (i.e., alevins)) are used along with the spawning and pre-spawning distributions and river water temperature data to compute water temperature-induced percent losses of eggs and alevins (USBR Unpublished Work). The updated timeline for the Chinook salmon spawning nd incubation life stages as used in the USBR Chinook salmon water temperature mortality model is shown in Table 4.1-1.

The USBR Chinook salmon water temperature mortality model calculates daily thermal units (TU) (i.e., a difference between water temperature (°F) minus 32°F) to track life stage development (USBR Unpublished Work). An accumulated thermal unit (ATU) can be defined as each degree Celsius above zero (Raleigh et al. 1986), or as degrees Fahrenheit above freezing, accumulated during a 24-hour period (DFG 1998) (e.g., 1000°C ATUs = 50 days at 20°C or 100 days at 10°C; 1000°F ATUs = 50 days at 52°F or 100 days at 42°F). Eggs are assumed to hatch after exposure to 750^{o}F ATUs following fertilization. Fry are assumed to emerge from the gravel into the pre-emergent fry stage after exposure to 750°F ATUs following egg hatching (USBR Unpublished Work). The water temperature-induced mortality rates for fertilized eggs, which is the most sensitive life stage, range from eight percent in 24 days at 57°F to 100 percent in seven days at 64°F or above (Table 4.1-2). On the lower Feather River, most salmon spawning generally occurs above Honcut Creek (USBR Unpublished Work).

Table 4.1-1. Estimated timeline of the Chinook salmon spawning and incubation life stages in the lower Feather River.

<table>
<tr><th>Year</th><th>Reach</th><th>Date Spawners Arrive</th><th>Peak Spawner Arrival Date</th><th rowspan="5">Pre-spawning Mortality</th><th>Date Spawning Begins</th><th>Date of Spawning Peak</th><th rowspan="5">Egg Mortality</th><th>Date Eggs Hatch</th><th rowspan="5">Pre-emergent Fry Mortality</th><th>Emergence Date</th></tr>
<tr><td rowspan="2">2002</td><td>LFC</td><td>July 2</td><td>September 16</td><td>July 15</td><td>September 29</td><td rowspan="4">After 750^{o}F ATU requirement is reached</td><td rowspan="4">After 750^{o}F ATU requirement is reached</td></tr>
<tr><td>HFC</td><td>June 6</td><td>October 15</td><td>June 19</td><td>October 28</td></tr>
<tr><td rowspan="2">2003</td><td>LFC</td><td>June 29</td><td>September 12</td><td>July 12</td><td>September 25</td></tr>
<tr><td>HFC</td><td>May 23</td><td>October 26</td><td>June 5</td><td>November 8</td></tr>
</table>

The Chinook salmon water temperature mortality model is limited to water temperature-induced mortality effects on the early life stages of Chinook salmon (USBR Unpublished Work). It does not evaluate potential direct or indirect temperature impacts on later life stages, such as emergent fry, smolts, juvenile out-migrants, or adults (USBR Unpublished Work). Also, it does not consider other factors that may affect salmon mortality, such as instream flows, gravel sedimentation, diversion structures, predation, and ocean harvest (USBR Unpublished Work).

For the purpose of this modeling analysis, the study area is broken down into nine reaches utilized in the USBR Chinook salmon water temperature model to spatially distribute the salmon in the lower Feather River (Table 4.1-3). The LFC consists of the upper three reaches and the lower six reaches represent the HFC, with only reaches four and five in the HFC actually containing spawners. The spatial distributions of salmon within the nine model reaches each spawning year (i.e., Reach Distribution or RD in Table 4.1-4) are estimated from carcass survey data. The mortality estimates in the nine reach distributions sum to 100 percent. The estimates of pre-spawning and spawning temporal distributions of Chinook salmon within these nine reaches also are based on carcass survey data from DWR. Pre-spawning and spawning distributions (PSD and SD in Table 4.1-4) are estimated from the carcass surveys performed in the LFC and HFC. Thus, the PSD and SD in the LFC sum to 1, and the PSD and SD in the

HFC also sum to 1. By multiplying the LFC pre-spawning and spawning distributions by the three reach distributions utilized in the early life stage mortality model for the LFC, estimates of temporal pre-spawning and spawning distributions of Chinook salmon within each of the three upper reaches were obtained. Similarly, by multiplying the HFC pre-spawning and spawning distributions by the six reach distributions utilized in the USBR model for the HFC, estimates of temporal pre-spawning and spawning distributions of Chinook salmon within each of the six reaches in the HFC were obtained. The resultant products for each of the nine reach-specific pre-spawning temporal distributions sum to 100 percent, as do the nine reach-specific spawning temporal distributions. To estimate the initial LFC and HFC pre-spawning and spawning distributions, it was assumed that spawning occurs two weeks after arrival (USBR Unpublished Work) and that carcasses appeared three weeks after spawning, for a five-week lag between the arrival of spawners and the carcass distribution.

Table 4.1-2. Water temperature-induced mortality schedules used in the USBR Chinook salmon water temperature mortality model.

Mortality rates for Chinook salmon eggs and alevins versus water temperature						
	Eggs in adults		Eggs in redds		Pre-emergent Fry (Alevins)	
Exposure Temperature (°F)	Mortality Schedule (Rate at Exposure Time)	Daily Pre-spawning Mortality Criteria[a] (PSC)	Mortality Schedule (Rate at Exposure Time)	Daily Egg Mortality Criteria[a] (EC)	Mortality Schedule (Rate at Exposure Time)	Daily Pre-emergent Fry Mortality Criteria[a] (FC)
< 52	Natural rate	-	Natural rate	-	Natural rate	-
52	Natural rate	-	Natural rate	-	Natural rate	-
53	1% @ 30 days	0.034	Natural rate	-	Natural rate	-
54	5% @ 30 days	0.171	Natural rate	-	Natural rate	-
55	10% @ 30 days	0.351	Natural rate	-	Natural rate	-
56	15% @ 30 days	0.540	Natural rate	-	Natural rate	-
57	21% @ 30 days	0.783	8% @ 24 days	0.347	Natural rate	-
58	29% @ 30 days	1.135	15% @ 22 days	0.736	Natural rate	-
59	38% @ 30 days	1.581	25% @ 20 days	1.428	10% @ 14 days	0.750
60	47% @ 30 days	2.094	50% @ 12 days	5.613	25% @ 14 days	2.034
61	55% @ 30 days	2.627	80% @ 15 days	10.174	50% @ 14 days	4.830
62	64% @ 30 days	3.348[b]	100% @ 12 days	31.871	75% @ 14 days	9.428
63	-	-	100% @ 11 days	34.207	100% @ 14 days	28.031
64	-	-	100% @ 7 days	48.205	100% @ 10 days[b]	36.904
> 64	-	-	100% @ 7 days	48.205[b]	100% @ 10 days[b]	36.904[b]

[a] Uses formula derived by Ricker 1975.
[b] Same mortality rate is applied for greater temperatures.
Source: U.S. Bureau of Reclamation 1991 (as modified by Rowell pers. comm.) and Bratovich 1995
Natural rate accounts for mortality due to all possible effects other than temperature.

Table 4.1-3. Reach distributions utilized for the USBR Chinook salmon water temperature mortality model in the lower Feather River from 2002 to 2004.

	Reach No.	Reach boundaries (RM)	Reach Distribution (%)	
			2002 - 2003	*2003 - 2004*
LFC	1	Fish Barrier Dam (RM 67.3) – RM 65	27.9	36.7
	2	RM 65 – RM 62	38.0	27.9
	3	RM 62 – Upstream of Afterbay (RM 59)	15.2	10.5
	Total		**81.1**	**75.1**
HFC	4	Downstream of Afterbay Outlet (RM 59) – RM 55	12.2	16.1
	5	RM 55 – Gridley Bridge (RM 51)	6.7	8.8
	6	Gridley Bridge (RM 51) – RM 47	0.0	0.0
	7	RM 47 – Honcut Creek (RM 44)	0.0	0.0
	8	Honcut Creek (RM 44) – Yuba River (RM 27.7)	0.0	0.0
	9	Yuba River (RM 27.7) – Mouth	0.0	0.0
	Total		**18.9**	**24.9**

Table 4.1-4. Variables used in the mortality model and associated definitions.

Known variables/values:	
Distributions	PSD (pre-spawning)
	SD (spawning)
	RD (reach)
Mortality Criteria	PSC (pre-spawning)
	EC (egg)
	FC (pre-emergent fry)
Water temperature Data	
Computed variables/values:	
Distributions	AD (adult)
	ESD (spawned eggs)
	ED (egg)
	FD (pre-emergent fry)
Development variables	EFRY (emergent fry)
	FRY (pre-emergent fry)
Kills (losses)	AKIL (eggs in adults)
	EKIL (egg)
	FKIL (pre-emergent fry)
Mortalities	EM (egg)
	PSM (pre-spawning)
	FM (pre-emergent fry)

Known values and distributions including data on mortality rates, pre-spawning arrival, spawning, reach breakdown and water temperature are input into the USBR Chinook salmon water temperature mortality model. The Chinook salmon water temperature mortality model then calculates proportional population distributions and mortalities for the early life stages and outputs those mortalities on a daily, monthly or annual basis. A list of variables used in the mortality models and their definition is shown in Table 4.1-4.

To supplement text descriptions of the Chinook salmon water temperature mortality model for the lower Feather River calculation procedure, example computation results from the HFC in the lower Feather River during the 2002/2003 spawning and incubation season are provided below.

4.1.2 Water Temperature

The USBR Chinook salmon water temperature mortality model utilizes reach-specific daily water temperature values to estimate daily mortalities. Daily water temperature data for the Feather River from February 2002 to February 2004 were obtained from DWR water temperature logging sites (Figure 4.1-1). The water temperature data contained temporal and spatial data gaps that needed to be filled for use with the USBR Chinook salmon water temperature mortality model. The water temperature data were then adjusted to conform to the reaches used in the USBR Chinook salmon water temperature mortality model, because the logger sites did not necessarily correspond with the USBR Chinook salmon water temperature mortality model reaches (refer to section 4.2.2 for details).

4.1.3 Early Life stage Mortality

In the USBR Chinook salmon water temperature mortality model, early life stage mortalities are calculated using relationships between mortality and water temperature (Table 4.1-2) combined with estimations of proportional populations (i.e., early life stage percent population distributions) per river reach and through time. After daily water temperatures have been calculated, daily mortality rates are used with water temperature data to estimate daily, monthly and annual mortalities (or percent losses) to the early life stages.

4.1.4 Daily Mortality Rates

Mortality schedules, shown in Table 4.1-2, provide information about relationships between water temperature and mortality rates by early life stages of Chinook salmon (Ricker 1975; Rowell 1994). For example, the mortality schedule for fertilized eggs contains mortality rates ranging from 8 percent after 24 days of exposure to 57°F water temperatures to 100 percent after seven days of exposure to 64°F or higher water temperatures. In the Chinook salmon water temperature mortality models, information from the mortality schedules is used to compute daily mortality criteria, which are applied to daily proportional population estimates to calculate percent population losses for each early life stage. Daily mortality criteria are calculated in the salmon mortality models for all early life stages (pre-spawned eggs or eggs in adults (PSC), eggs in redds (EC), and pre-emergent fry or alevin (FC) on a daily basis using daily water temperatures and mortality rates (Table 4.1-2).

First, the instantaneous mortality rate (z) is calculated: $z = \frac{\ln N_0 - \ln N_t}{dt}$ *,(Ricker 1975)*

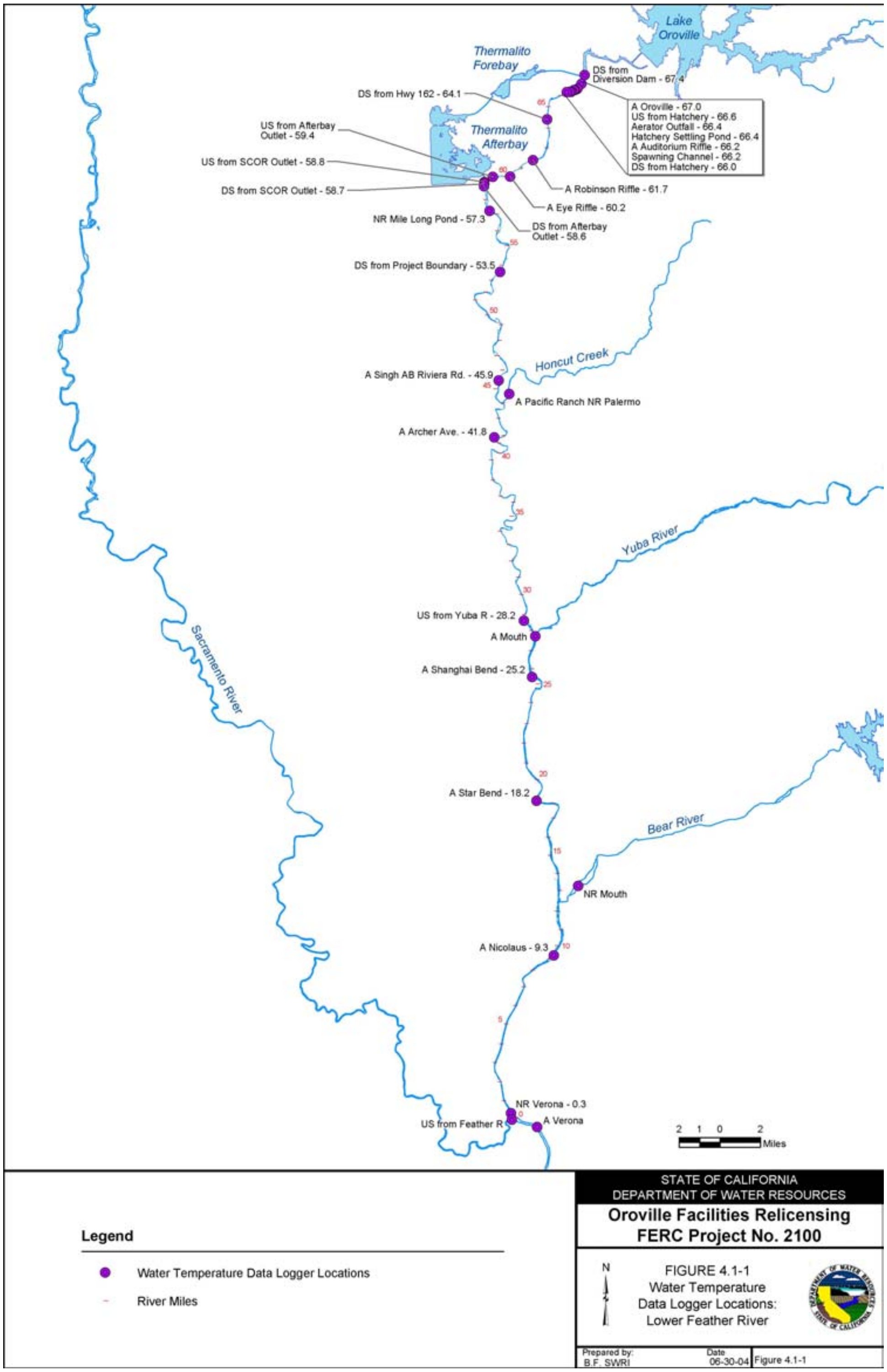

Figure 4.1-1. Water temperature data logger locations in the lower Feather River.

Where,

N_o is the proportion of eggs or fry at beginning of exposure to a exacting water temperature,

N_t is the proportion of eggs or fry surviving after a time interval *"t"* at a particular water temperature, and

dt is the time interval over which the mortality occurs.

The daily mortality criteria (e.g., PSC, EC or FC) can then be calculated by transforming the instantaneous mortality rate (z) into a daily mortality value using the following equation:

$$PSC, EC \ or \ FC = (1 - e^{-z}) \ * \ 100$$

As an example, the estimated mortality criterion for pre-spawned (*in vivo*) Chinook salmon eggs at 57°F is equivalent to 21 percent within 30 days (Table 4.1-2). Assuming that 100 percent of the eggs are alive at the beginning of the time period, then the instantaneous mortality rate (z) and pre-spawning mortality criteria (PSC) are calculated as follows:

$$z = \frac{\ln(100\%) - \ln(100\% - 21\%)}{30 \ days} = \frac{\ln(1) - \ln(0.79)}{30}$$

$$z = \frac{0 - (-0.2357)}{30} = 0.007857$$

$$PSC = \left(1 - e^{-0.007857}\right) * 100 = 0.783$$

Because the mortality schedules (PSC, EC, and FC) only provide mortality rates associated with whole number water temperature values, mortality criteria associated with non-integer water temperatures values are calculated in the USBR Chinook salmon water temperature mortality model through linear interpolation (Figure 4.1-2). The ranges of values associated with integer and non-integer water temperatures are called pre-spawned eggs (i.e., eggs in adults), eggs in redds and pre-emergent fry (alevin) mortality criteria (PSM, EM and FM) and are used in the USBR Chinook salmon water temperature mortality model to estimate daily percent losses to the three early life stages.

4.1.5 Pre-Spawning and Spawning Distributions

The calculated daily mortality rates are combined with daily population proportion estimates to calculate percent population mortality for each early life stage (Figure 4.1-

2). The pre-spawning distribution (PSD) is a daily estimate of the proportion of Chinook salmon total run arriving with the purpose of engaging in spawning activities. The spawning distribution (SD) is a daily estimate of the percent of individuals in the total run participating in spawning activities.

In the modified USBR Chinook salmon water temperature mortality model, the pre-spawning and spawning distributions are temporal distributions based on carcass survey data (refer to section 4.2.1 for details). The Chinook salmon water temperature mortality model assumes that spawning occurs two weeks after arrival of adult salmon to the spawning grounds, and that carcasses appeared three weeks after spawning, based upon previous studies and a literature review. Therefore, there is a five-week lag between the arrival of spawners and the carcass distribution data.

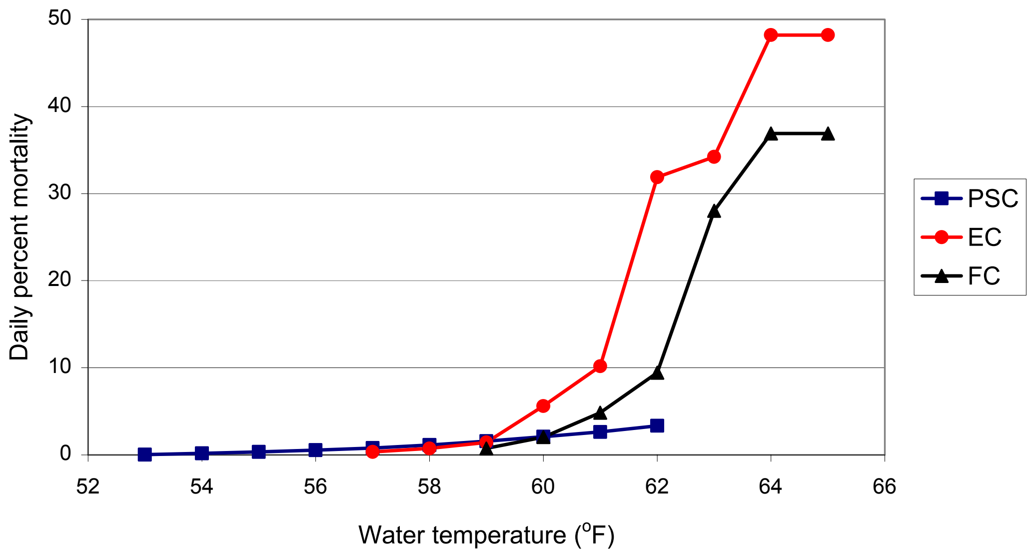

Figure 4.1-2. Water temperature-induced mortality criteria for pre-spawned (*in vivo*) eggs (PSM), eggs in redds (EM), and pre-emergent fry or alevin (FM) for Chinook salmon.

4.1.6 Adult Distribution and Pre-spawning Losses

The adult distribution (AD) is defined as the proportion of pre-spawning adults per day (USBR 1991). The adult distribution is calculated on a daily basis by subtracting the spawning distribution (SD) (Figure 4.2-3) from the pre-spawning distribution (PSD) (Figure 4.2-4), and multiplying the resulting difference by the reach distribution (RD) (Figure 4.1-3), and summing cumulatively: AD = AD (previous day) + (PSD – SD) * RD

If SD exceeds PSD, then AD is set equal to zero.

Water temperature-induced mortality of eggs inside adult female Chinook salmon (*in vivo*) mortality is referred to as AKIL, and is defined as the daily pre-spawned egg losses in percent (USBR 1991). AKIL refers refer specifically to the loss of eggs within adult salmon because pre-spawning mortality criteria are based on egg survival experiments, and are not based on adult survival (USBR 1991). *In vivo* egg mortality is calculated on a daily basis by multiplying the adult distribution by the pre-spawning mortality (PSM) value: AKIL = AD * PSM

The adult distribution (AD) is re-evaluated as the difference between the original adult distribution (above) and the *in vivo* egg mortality to determine pre-spawning losses to the adult distribution: AD (current day) = AD (current day) – AKIL (previous day)

If *in vivo* egg mortality exceeds the distribution value, then AD is set to zero.

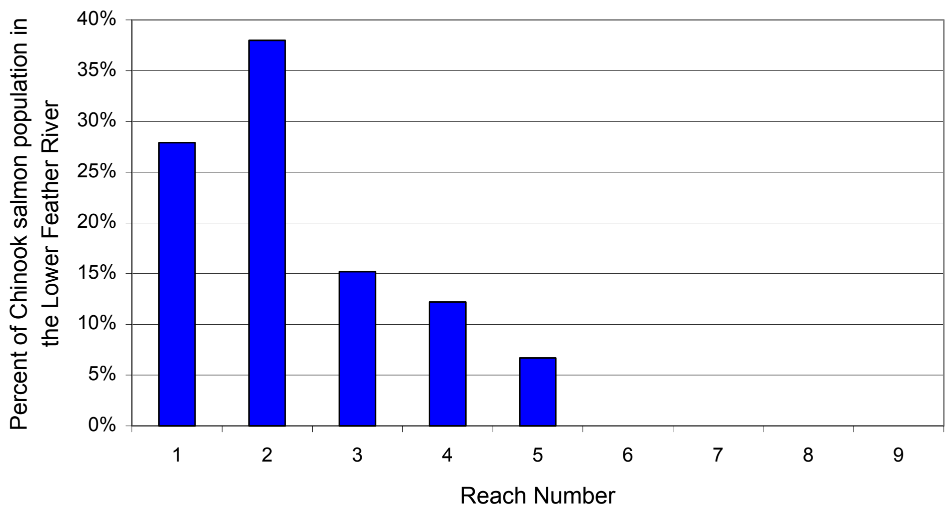

Figure 4.1-3. Adult Chinook salmon distribution by reach in the lower Feather River during the 2002/2003 spawning and incubation season.

Figure 4.1-4 shows the adult distribution and *in vivo* mortality for the HFC in 2002. *In vivo* mortality begins on June 5, 2002 because this is the first day that spawners arrive and water temperatures are high enough to cause some degree of mortality. *In vivo* mortality ends on November 1, which is the same day as the end of the adult distribution. The sudden drop in the adult distribution is a response to high spawning activity during the month of October (Figure 4.2.3). The daily percentage of *in vivo* mortality remains below one percent, but the total amount of *in vivo* mortality summed over the entire year in the HFC is 2.72 percent, with 1.8 percent mortality occurring in October. The adult distribution (AD), as well as the egg and pre-emergent fry life stage distributions (ED and FD), are cumulative sums.

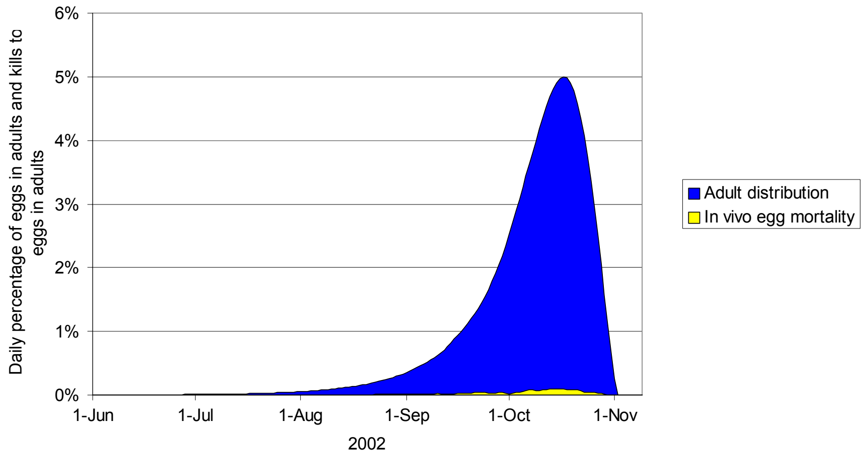

Figure 4.1-4. Adult Chinook salmon distribution and adjustment for *in vivo* egg mortality in the HFC of the lower Feather River during the 2002/2003 spawning and incubation season.

4.1.6 Spawned Egg Distribution Adjusted for Pre-spawning Losses

The spawned egg distribution (ESD) is an estimate of the distribution of eggs that have been spawned including percent losses due to *in vivo* mortality. The calculations for the spawned egg distribution are similar to the adult distribution, except the pre-spawning distribution (PSD) is not incorporated and the ESD is not summed cumulatively: ESD = SD * RD

The adjusted spawned eggs distribution is calculated by subtracting the previous days losses due to *in vivo* mortality (AKIL) from the current daily spawned egg distribution: ESD (current day) = ESD (current day) – AKIL (previous day)

If the number of eggs lost due to *in vivo* mortality is greater than the spawned egg distribution of the current day (resulting in a negative value for the ESD), then the spawned egg distribution for the current day (negative value) is added to the spawned egg distribution for the following day and the current days value is reset to zero. This process is repeated until the number the number of eggs lost no longer exceeds the number of spawned eggs. A common effect of *in vivo* mortality is to shift the onset of the spawned egg distribution to a few days after the spawning distribution (SD) because *in vivo* mortality begins two weeks prior to the spawning distribution, and the cumulative percent losses in those two weeks can exceed the spawned egg distribution.

Figure 4.1-5 shows the spawned egg distribution and *in vivo* mortality in the HFC for 2002. The spawned egg distribution begins on June 21 and ends on December 9, which is the end of the spawning distribution. The spawning distribution (SD) begins on June 19, but the cumulative losses due to *in vivo* mortality, which starts on June 6, push the starting date of the spawned egg distribution back to June 21.

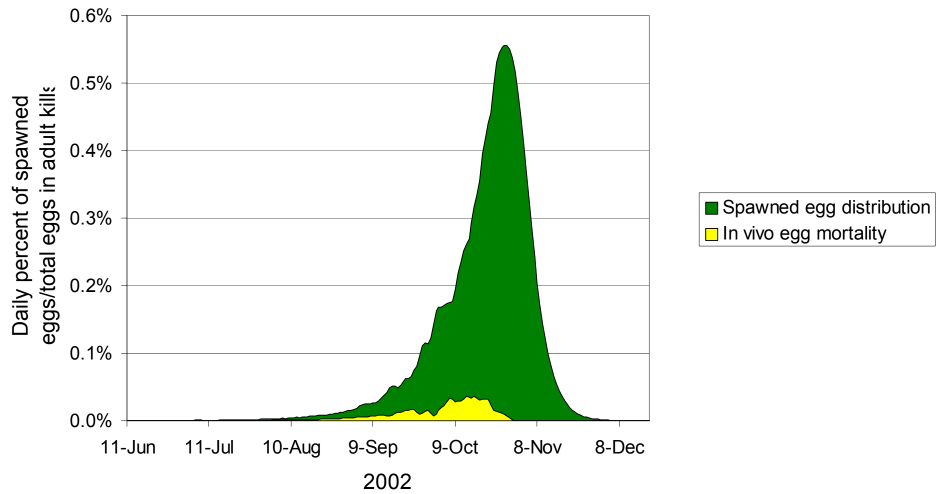

Figure 4.1-5. Spawned egg distribution and adjustment for *in vivo* egg mortality in the HFC of the lower Feather River during the 2002/2003 spawning and incubation season.

4.1.7 Pre-emergent Fry Development

Eggs and pre-emergent fry are assumed to hatch upon exposure to 750°F ATUs following fertilization (Rowell 1990). The number of pre-emergent fry (FRY) is calculated in the salmon mortality models based on the spawned egg distribution. Once eggs are spawned and the 750°F ATU requirement is reached, the number of pre-emergent fry on the current day is set to the number of spawned eggs (ESD) from the date when they were first spawned. No percent losses are assessed and the number of pre-emergent fry is not summed cumulatively here: FRY (date 750°F ATU reached) = ESD (date of spawning)

Eggs that were spawned on different days may hatch on the same day because development varies with water temperature.

Figure 4.1-6 shows the number of days required for pre-emergent fry development in the HFC during 2002. In the HFC during 2002, the 750°F ATU requirement is reached, on average, after about 35 days from the beginning of the spawned egg distribution. Spawned eggs appear in the HFC on July 13th according to the USBR Chinook salmon water temperature mortality model, but, due to egg mortality (Figure 4.1-8), hatching does not begin until November 2nd. The number of days necessary for pre-emergent fry development increases as water temperatures decrease into winter, with a maximum of 42 days.

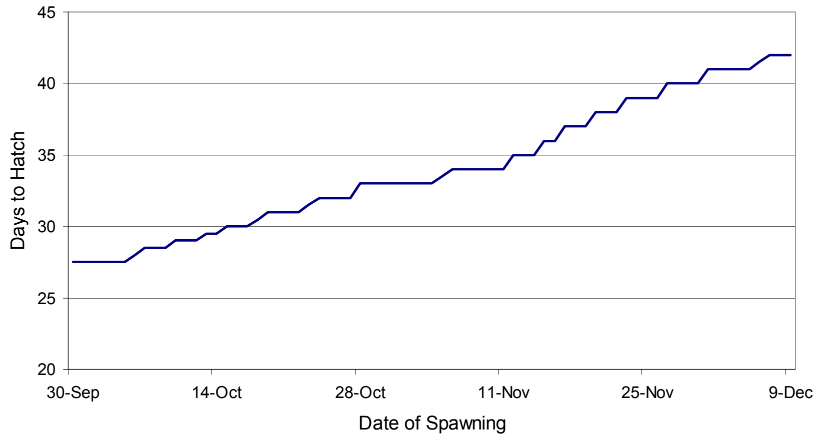

Figure 4.1-6. Average number of days required for hatching for each spawning date in the HFC of the lower Feather River during the 2002/2003 spawning and incubation season.

Figure 4.1-7 shows the development of pre-emergent fry (hatching) throughout 2002 in the HFC, which is adjusted for pre-emergent fry mortality. A significant amount of egg mortality starting in mid-July pushes the onset of hatching back to November 2. Hatching ends on January 20, 2003. Eventually fewer eggs hatch on the same day since the water temperature decreases with the onset of winter (requiring a longer time for development). However, it is possible for eggs that were spawned on different days to hatch on the same day during the summer and early fall when water temperatures are increasing. Development of pre-emergent fry (FRY) differs from the pre-emergent fry distribution (FD) in that the pre-emergent fry distribution takes percent losses due to pre-emergent fry mortality and emergence into account. In addition, the pre-emergent fry distribution (FD) is a cumulative distribution, although the development of pre-emergent fry (FRY) is not cumulative.

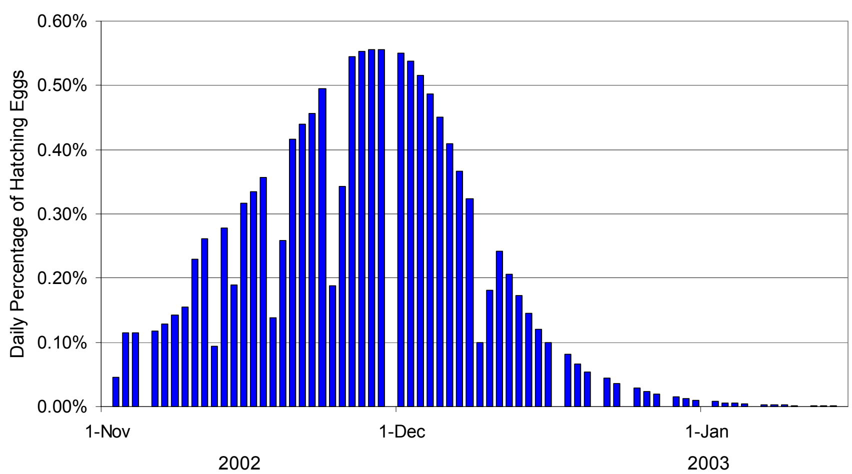

Figure 4.1-7. Pre-emergent fry development (hatching) over time, adjusted for *in vivo* egg mortality in the high low channel of the lower Feather River during the 2002/2003 spawning and incubation season.

4.1.8 Egg Distribution and Losses

The daily egg distribution (ED) is defined as the percentage of eggs present (within the redds and not in adults) on each day (USBR 1991). It is calculated by adding up the spawned egg distribution (ESD) to the previous days egg distribution, and then subtracting the number of eggs that have developed to pre-emergent fry (FRY) along with any losses due to egg mortality (EKIL): ED = ESD + ED (previous day) – FRY.

Egg mortality is estimated by multiplying the egg distribution by the egg mortality criteria (EM): EKIL = ED * EM.

Egg mortality is subtracted from the egg distribution to account for percent losses to the egg distribution: ED = ED – EKIL.

Egg mortality also affects the number of pre-emergent fry on the next day: FRY (next day) = FRY (next day) – EKIL (current day).

Egg mortality can exceed the number of pre-emergent fry for the current day (resulting in a negative number). This negative value for pre-emergent fry for the current day is added up to the number of pre-emergent fry for the next day, and the number or pre-emergent fry for the current day is set to zero. This process is repeated until egg mortality no longer exceeds the number of pre-emergent fry. The number of pre-emergent fry is then subtracted from the egg distribution once the number of egg mortalities does not exceed the number of pre-emergent fry.

Figure 4.1-8 depicts the adjusted egg distribution and egg mortality in the HFC during the 2002/2003 spawning and incubation season. For this year and reach, egg mortality begins on June 21 and continues until October 31, whereas the eggs appear also on June 21 but are gone (all hatched) by January 20, 2003. The daily mortality percentage is below one percent for eggs, but the total annual amount of mortality is 3.0 percent of the total run when summed across the entire year.

4.1.9 Emergent Fry Development

In the Chinook salmon water temperature mortality model, the emergent fry (EFRY) development is similar to the pre-emergent fry development calculations discussed above. Emergent fry also need 750^{o}F ATUs to reach maturity in this model: EFRY (date 750^{o}F ATU reached) = FRY (date eggs hatched)

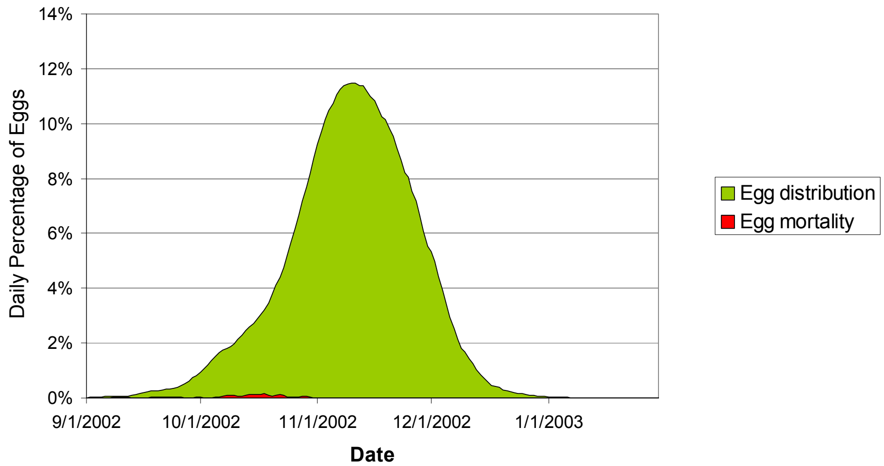

Figure 4.1-8. Egg distribution and adjustment for egg mortality in the HFC of the lower Feather River in the 2002/2003 spawning and incubation season.

Eggs that hatched on different days may have fry emerge on the same day because development varies with water temperature. Figure 4.1-9 indicates the number of days to emergence from the date of hatching, with an average of 40 days. Figure 4.1-10 shows emergence in the HFC of the lower Feather River during the 2002/2003 spawning and incubation season. Emergence begins on December 5, which is approximately thirty days after the beginning of hatching (November 2). No pre-emergent fry mortality occurred in the HFC, thus pre-emergent fry mortality does not influence dates and values for emergence in the HFC in 2002/2003.

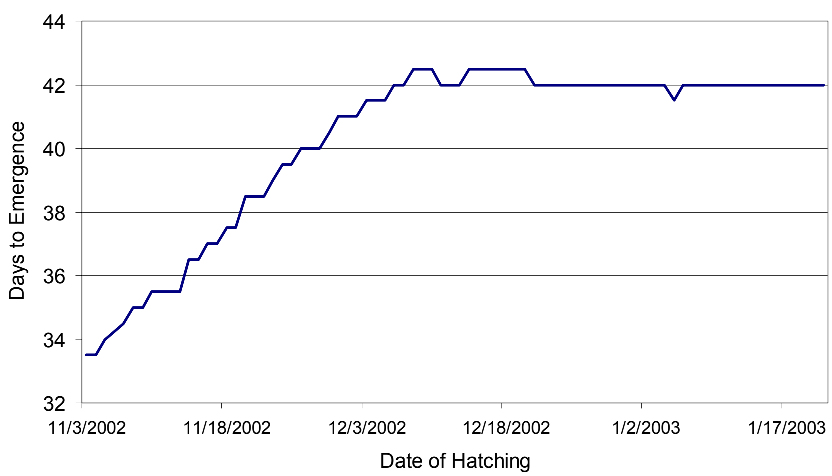

Figure 4.1-9. Average number of days required for fry emergence in the HFC of the lower Feather River during the 2002/2003 spawning and incubation season.

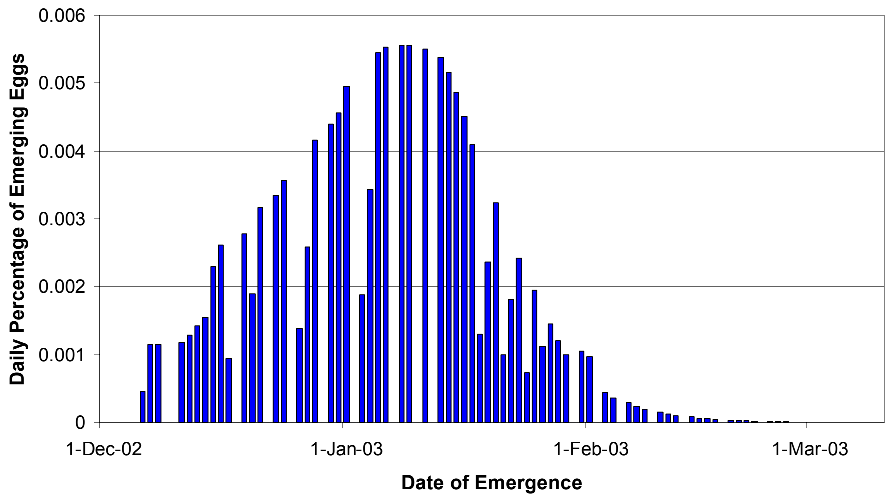

Figure 4.1-10. Chinook salmon emergent fry development over time, adjusted for egg mortality in the HFC of the lower Feather River in the 2002/2003 spawning and incubation season.

4.1.10 Pre-Emergent Fry (alevin) Distribution and Losses

The pre-emergent fry distribution is defined as the percentage of pre-emergent fry present each day (USBR 1991). The calculations for pre-emergent fry distribution (FD) and percent losses are similar to the egg distribution and percent losses calculations discussed above: FD = FRY + FD (previous day) – EFRY.

Pre-emergent fry losses (FKIL) are estimated by multiplying the pre-emergent fry distribution (FD) by the pre-emergent fry (alevin) mortality value (FM): FKIL = FD * FM.

Pre-emergent fry losses are subtracted from the pre-emergent fry distribution to account for percent losses: FD = FD – FKIL.

The number of pre-emergent fry losses also affects the number of emergent fry on the following day: EFRY (next day) = EFRY (next day) – FKIL (current day).

After the emergent fry distribution is summed cumulatively, the pre-emergent fry distribution is re-evaluated to reflect cumulative percent losses as pre-emergent fry begin to emerge.

Pre-emergent fry losses can exceed the number of emergent fry for the current day (resulting in a negative number). This negative value for emergent fry for the current day is added to the number of emergent fry for the next day, and the number of emergent fry for the current day is set to zero. This process is repeated until the number of pre-emergent fry losses no longer exceeds the number of emergent fry. The number of emergent fry is then subtracted from the pre-emergent fry distribution once the number of pre-emergent fry losses does not exceed the number of emergent fry.

Figure 4.1-11 shows the adjusted pre-emergent fry (alevin) distribution in the HFC of the lower Feather River in 2002/2003, which begins on November 2 (the first day of hatching) and ends on March 2 (the last day of emergence). According to the USBR Chinook salmon water temperature mortality model, there are no pre-emergent fry losses in the HFC because hatching starts on November 2 (Figure 4.1-12) when water temperatures are not warm enough to induce pre-emergent fry mortality.

4.1.11 Daily, Monthly, and Annual Mortality

To determine the total water temperature-induced mortality of Chinook salmon early life stages, total losses for all reaches for eggs in adults, eggs in redds, and pre-emergent fry are summed cumulatively on a daily basis in the USBR Chinook salmon water temperature mortality model. Thus, the results can be reported on a monthly and annual basis for each run.

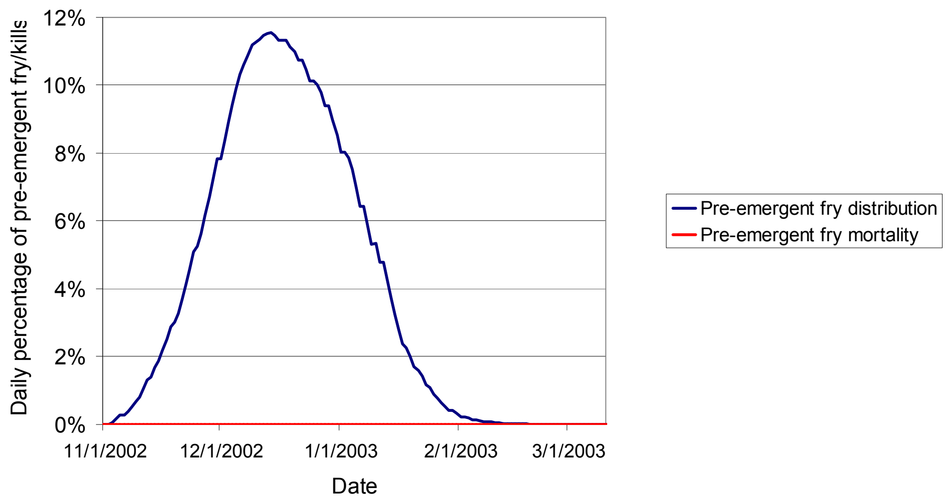

Figure 4.1-11. Pre-emergent fry (alevin) distribution and mortality (no mortality occurred) in the HFC of the lower Feather River during the 2002/2003 spawning and incubation season.

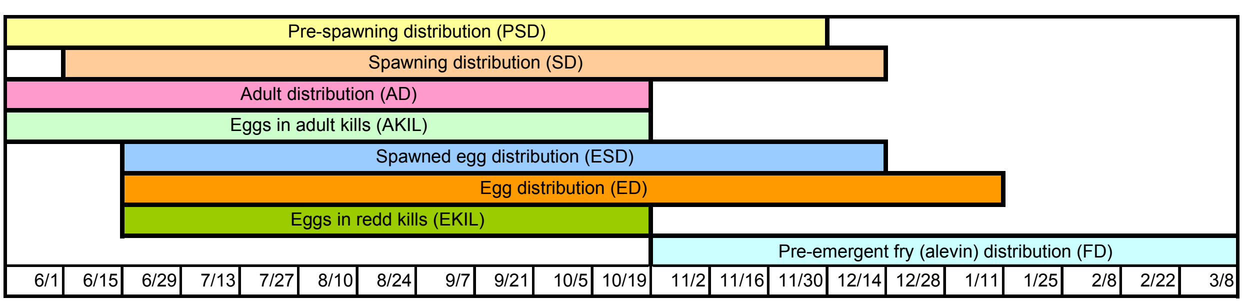

Figure 4.1-12. Time-line for Chinook salmon early life stage development in the HFC of the lower Feather River during the 2002/2003 spawning and incubation season.

4.1.12 SWRI modifications of the USBR Chinook salmon water temperature mortality model

In March of 2004, SWRI modified the USBR Chinook salmon water temperature mortality model for the lower Feather River by incorporating up to date information on the temporal distribution of spawning activity and daily water temperature data.

This modeling approach estimates the percentages of Chinook salmon egg and alevin losses due to water temperature-induced mortality, based upon new pre-spawning and spawning temporal distributions derived from shifted smoothed carcass distributions, and from calculated mean daily water temperature data throughout the pre-spawning, spawning and incubation periods of Chinook salmon in the lower Feather River during the 2002/2003 spawning and incubation season. New pre-spawning, spawning and reach distributions were created to reflect the most recent (2002/2003) carcass survey data. Please refer to sections 4.2.1 through 4.2.4 for details concerning the updated pre-spawning and spawning distributions, and for reach distributions see Table 4.1-3.

In former applications of the USBR Chinook salmon water temperature mortality model, monthly temperature output was utilized by interpolating the monthly values into daily values. In this model, daily temperature data were recorded from various locations on the lower Feather River (Figure 4.1-1) for use as the input water temperature file. Please refer to sections 4.2.5 through 4.2.7 for details regarding water temperature data.

4.1.13 Rationale for modifications

4.1.13.1 Pre-spawning and spawning distributions of the USBR Chinook salmon water temperature mortality model

The pre-spawning and spawning distributions are very important input variables to the USBR Chinook salmon water temperature mortality model because these distributions provide the daily proportions of pre-spawners and spawners respectively.

The documentation provided by USBR (2003) accompanying the USBR Chinook salmon water temperature mortality model described assumptions about the temporal pre-spawning and spawning distributions of Chinook salmon in the lower Feather River. This model assumes pre-spawning distributions starting on October 9 and 16, peaking on November 4 and 18 in the LFC and HFC, respectively, and ending on December 18. This model also assumes spawning distributions beginning on October 23 and 30, and peaking on November 18 and December 2 in the LFC and HFC, respectively, and ending January 1st (Figure 4.1-13). Further examination of the spawning distribution did not reveal the source of the data utilized to generate the temporal spawning distribution. Comparison of the peaks of the spawning distribution used in the USBR Chinook salmon water temperature mortality model with the carcass temporal distributions from

2000 to 2003 suggest that the spawning distribution originally used in the USBR Chinook salmon water temperature mortality model does not correspond with the temporal distribution of carcasses observed during the carcass surveys (Table 4.1-5).

Table 4.1-5. Dates of occurrence of the maximum number of carcasses in the LFC and HFC of the lower Feather River during the 2000 through 2003 carcass surveys, and the maximum proportion of spawners under the USBR spawning distribution (SD).

Carcass survey	LFC	HFC
2000	10/20/00	11/22/00
2001	11/01/01	11/15/00
2002	10/26/02	11/22/02
2003	10/24/03	11/29/03
USBR SD	11/18/02	12/02/02

The temporal peaks in the spawning distributions in the USBR model occur after the peaks in the carcass surveys, suggesting that the spawning distribution may not be appropriate in the current situation because the peaks of the carcass distributions cannot precede the peaks in the spawning distributions. The pre-spawning distributions in the USBR model were obtained by shifting the spawning distribution backward by two weeks.

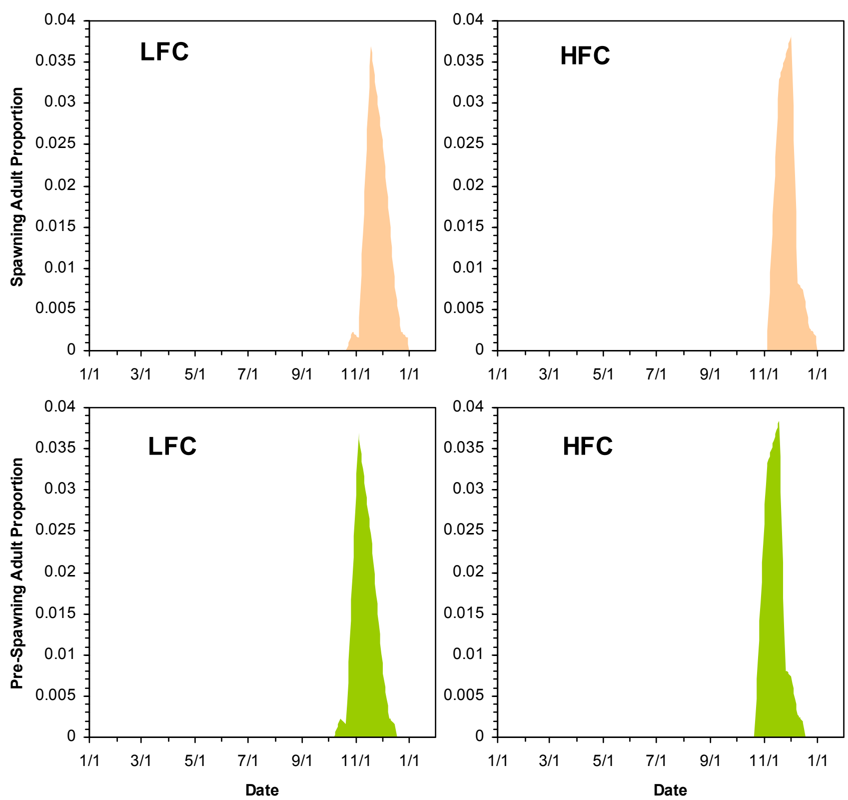

Figure 4.1-13. Pre-spawning and spawning distributions utilized by the USBR Chinook salmon water temperature mortality model in the LFC and HFC of the lower Feather River.

4.1.13.2 Water Temperature Daily Records as an Input to the USBR Chinook Salmon Water Temperature Mortality Model

The USBR Chinook salmon water temperature mortality model uses the results from the USBR water temperature model to generate daily water temperature values for each of the nine model reaches (Table 4.1-3). Because the water temperature model results are reported as monthly values at various river locations called "nodes" that do not coincide with the limits of the nine river reaches used by the USBR Chinook salmon water temperature mortality model, the mortality model first distributes the monthly water temperatures at the nodes throughout the appropriate river reaches to estimate monthly water temperatures in each of the nine river reaches. Depending on the river reach, the redistribution of the node monthly values is performed through the averaging of the values at two neighboring nodes, or through the linear interpolation between the monthly values of two adjacent nodes.

After the USBR Chinook salmon water temperature mortality model has calculated the monthly water temperature values at each of the nine river reaches, these monthly values are distributed into daily values by reach. In this process, daily water temperature values for January 1 through January 15 and for December 16 through December 31 are considered equal to the monthly river reach water temperatures. Daily water temperatures for the remaining dates are computed as linear interpolations between the monthly river reach water temperatures.

Because daily records of water temperature for 2002 and 2003 were readily available for the lower Feather River, it was considered an enhanced modeling approach to utilize these existing data, instead of using linearly interpolated daily water temperature data obtained from monthly water temperature data. Sections 4.2.5 through 4.2.7 below, describe the calculations used to generate daily river reach water temperatures.

4.2 HOW AND WHERE THE STUDIES WERE CONDUCTED

SWRI modified the USBR Chinook salmon water temperature mortality model to evaluate the effect of water temperatures on Chinook salmon pre-spawned egg, eggs in redds, and alevin survival in the lower Feather River. The SWRI modeling approach required the following data:

1) Individual-day Chinook salmon carcass counts in the LFC and HFC from the carcass survey extended from September 3 through December 19, 2002 (DWR, unpublished data); and
2) Average mean daily water temperatures from 26 data loggers distributed throughout the LFC, HFC and downstream to the confluence with the Sacramento River from February 10, 2002 through April 15, 2003.

These data required some processing previous to their use in the estimation of water temperature effects on Chinook salmon eggs and alevin survival. Sections 4.2.1 through 4.2.4 below, describe the various calculations required to obtain spawning and pre-spawning temporal distributions from the original 2002/2003 carcass data. Sections 4.2.5 through 4.2.7 describe all the calculations involved in obtaining the daily mean water temperatures used by the modified Chinook salmon water temperature mortality model.

4.2.1 Temporal Distributions of Pre-Spawning and Spawning Activity

The USBR Chinook water temperature mortality model was updated using recent carcass distributions observed in the past four surveys, to estimate the pre-spawning and spawning temporal distributions. The analytical procedure utilized to estimate the pre-spawning and spawning temporal distributions from the 2002 carcass survey is described below.

4.2.2 Carcass Survey Data and Analysis

The evaluation of lower Feather River water temperature effects on Chinook salmon egg and alevin mortality was a multi-step procedure, which required that carcass survey data be utilized as an appropriate surrogate for the temporal distribution of spawning activity. The USBR Chinook salmon mortality model assumed that spawning occurs two weeks after arrival, and SWRI assumed that carcasses appeared three weeks after spawning. Therefore, a five-week lag occurs between pre-spawning (i.e., the arrival of spawners) and the carcass distributions. The estimation of the pre-spawning and spawning temporal distributions of Chinook salmon included the following five components:

1) Individual-day counts of carcasses were summed over the carcass survey period to obtain a cumulative distribution.
2) Asymmetric logistic curves were fitted to the observed cumulative distributions of carcasses to obtain the expected daily cumulative distributions of carcasses in the LFC and HFC of the lower Feather River.
3) The estimated daily distributions of carcasses were calculated by subtracting previous-day cumulative values from current-day cumulative values provided from the fitted asymmetric logistic curves.
4) The estimated daily distributions of carcasses were shifted 3 weeks earlier to account for the time interval between spawning and observation in the carcass survey, and to represent the daily spawning distributions.
5) The estimated daily distributions of carcasses were shifted 5 weeks earlier to account for the time interval between pre-spawning and observation in the carcass survey, and to represent the daily pre-spawning distributions.

Carcass count totals from the 2002 carcass survey in the lower Feather River were used to calculate the percent cumulative distribution of carcass counts, per study reach (LFC and HFC) and survey day. To smooth the cumulative distribution of carcass counts, the observed percentages were fitted to modeled curves using non-linear regression (e.g., minimum least-squares). An asymmetric logistic model (Figure 4.2-1) was fit to the cumulative distribution of Chinook salmon carcasses because, of several models examined, the asymmetric logistic model provided the smallest mean square error.

Both the LFC and HFC cumulative relative frequency distributions [$Y(\%)_i$] were fitted to asymmetric logistic curves to allow detecting any potential asymmetry of the observed distributions. The mathematical expression of this curve is:

$$Y(\%)_i = \frac{1}{\left(1+\exp\left(\alpha+\beta\times D_i\right)\right)^{1/\delta}},$$

Where,

- $Y(\%)_i$ is the sum of all carcasses counted until a particular sampling date "*i*" of the corresponding carcass survey, expressed as a percentage;
- α is the logistic parameter corresponding to the intercept;
- β is the logistic parameter corresponding to the slope;
- δ is the logistic parameter that controls the symmetry of the resulting curve, (if $\delta = 1$ the curve is the typical symmetrical logistic); and
- D_i is a continuous variable that measures the sampling date "*i*" as the number of days counted from the start of the carcass survey.

The estimated parameters of modeled asymmetric logistic curves fit to cumulative distributions of Chinook salmon carcasses in the LFC and HFC of the lower Feather River in 2002 are shown in Table 4.2-1.

Table 4.2-1. Parameter estimates (α, β and δ), number of observations (*n*) and total residual sum of squares (*RSS*) of modeled asymmetric logistic curves fit to Chinook salmon carcass cumulative distributions in the LFC and HFC of the lower Feather River in 2002.

Year	**2002**	
Reach	**LFC**	**HFC**
α	*29.637140*	*71.913785*
β	*-0.102145*	*-0.219998*
δ	*0.777501*	*3.605887*
n	*16*	*16*
RSS	*0.0009084*	*0.001230*

RSS is the total sum of the squared differences between observed and predicted values (i.e., residuals).

The observed cumulative distributions, fitted curves and total number of carcasses (*N*) are displayed in Figure 4.2-1.

The estimated daily distribution of carcasses (Figure 4.2-2) was calculated by subtracting previous-day cumulative values from current-day cumulative values provided by the asymmetric logistic lines in Figure 4.2-1. Because the asymmetric logistic curve used to smooth the carcass distributions is a continuous function, the resulting smoothed curves never attained a zero value at any date. In order to correct for this feature, the estimated daily distributions of carcasses were re-scaled as follows:

$$y_t = \frac{Round\left(\left(Y_{t+1} - Y_t\right) \times E, 0\right)}{\sum Round\left(\left(Y_{t+1} - Y_t\right) \times E, 0\right)},$$

Where,

y_t	is the scaled daily carcass proportion on day *"t"*;
E	is the Schaefer abundance estimate for the corresponding reach (LFC or HFC), and corresponding year (2002); and
$Round(...,0)$	indicates the rounding of the daily carcass proportion to the integer level.

The final scaled daily carcass proportions are displayed in Figure 4.2-2.

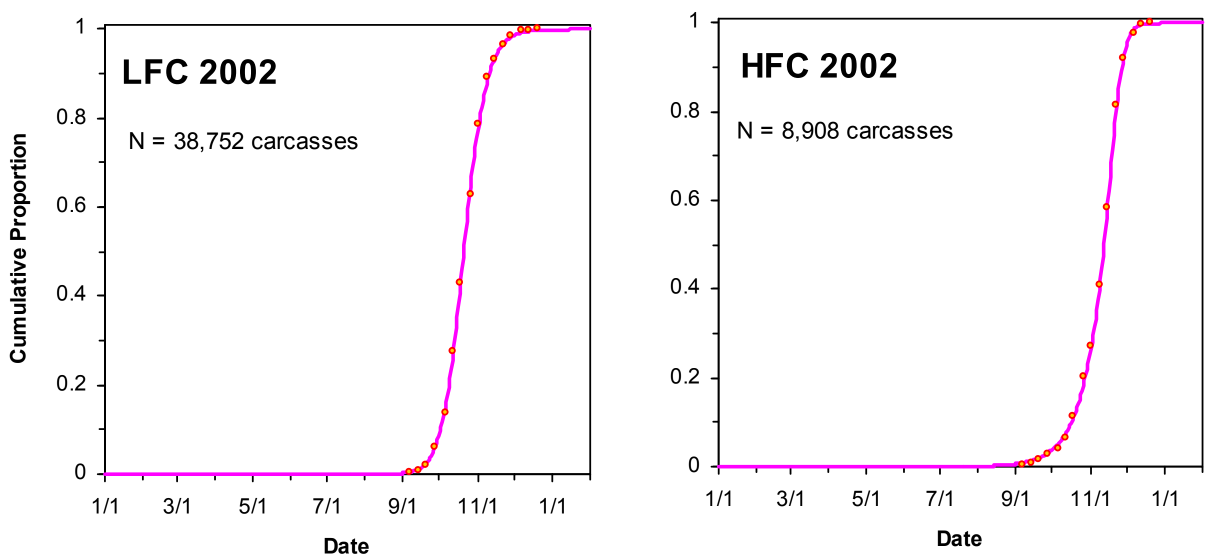

Figure 4.2-1. Cumulative distributions of Chinook salmon carcasses in the LFC and HFC, and the total number of carcasses (*N*) in the lower Feather River during 2002.
Note: Circles indicate observed cumulative counts, and the lines represent asymmetric logistic curves fitted to the data.

4.2.3 Estimation of Spawning Temporal Distribution

Based upon available literature and spawning timing analyses of fall-run Chinook salmon in the lower American River, the estimated daily distribution of carcasses was shifted 3 weeks earlier to account for the time interval between spawning and observation in the carcass survey. Hence, the smoothed daily carcass distributions (Figure 4.2-2) were shifted backwards three weeks to calculate approximately the spawning distribution for the LFC and HFC in 2002, which are depicted in Figure 4.2-3.

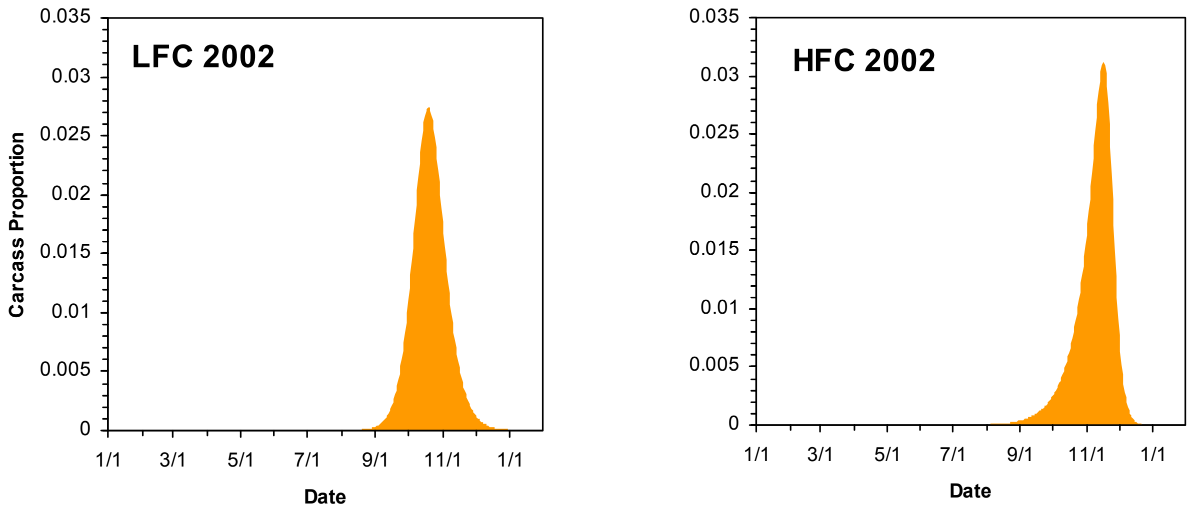

Figure 4.2-2. The estimated daily carcass proportions of Chinook salmon in the LFC and HFC of the lower Feather River during 2002.

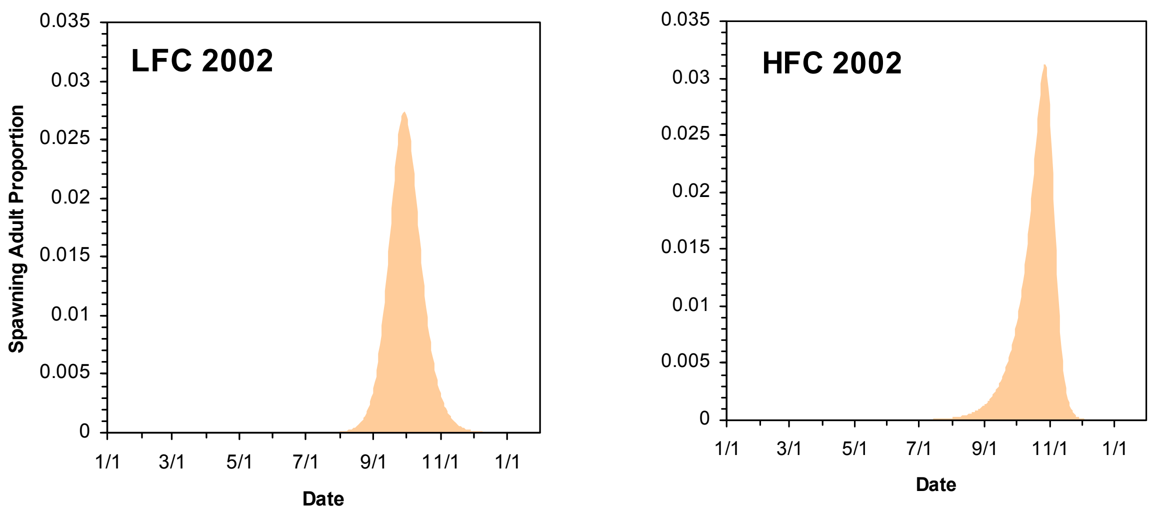

Figure 4.2-3. The estimated daily spawning distributions of Chinook salmon in the LFC and HFC of the lower Feather River during 2002.

The rationale of the three-week shift of the smoothed carcass distributions to estimate the spawning distributions was based upon previous SWRI studies and also on various literature references. Chinook salmon spawning has been reported to take place over a period of five to 14 days (Allen and Hassler 1986). Once spawning commences, the female will spend four to 25 days guarding her redd (Healey 1991). Life expectancy after spawning has been reported as two to four weeks (Briggs 1953). The extent of these events is likely water temperature-dependent, and may be shortened if spawning takes place at water temperatures above the adult's thermal preference. The interval of spawning activity also appears to be dependent on the arrival time of the spawning females, as early spawning females have been observed protecting their redds longer than later arriving females (Neilson and Banford 1983).

Neilson and Bandford (1983) reported that Chinook salmon in the Nechako River in British Columbia resided on redds from six to 25 days with a mean of 14.5 days for one study reach, and 15.4 days for another study reach. Similar results were reported from the Kenai River in Alaska where Burger et al. (1995) utilized radio telemetry to describe the timing and duration of spawning of two runs of Chinook salmon. Burger et al. (1985) reported that early run and late run Chinook salmon resided at spawning areas an average of 13 days and 18.4 days, respectively. Chinook salmon in the Morice River in British Columbia reportedly protected redds from four to 18 days with mean residence times of 7.7 days for late arriving spawners, and 13.1 days for early arriving spawners (Neilson and Geen 1981). Both the Morice and Nechako River populations were mainly stream-type Chinook salmon, even though scale analysis indicated the presence of ocean-type Chinook as well. Allen and Hassler (1986) reported that each Chinook salmon female/male spawn over a period of five to 14 days and may guard the nest from five to nine days after spawning (Vronskiy 1972), suggesting a redd residence time of between 10 and 23 days. SWRI (unpublished data) estimated the time between redd construction and carcass detection in the lower American River from 1992 through 1995. Earlier in the spawning season, the number of days separating these events varied from a low of 16.2 days to a high of 19.9 days with a mean of 17.6 days. Later in the spawning season, the numbers of days separating redd construction and carcass detection was between 19.9 to 24 days with a mean of 21.3 days. Given this information, one can reasonably assume that, in general, two to four weeks elapse between redd construction and carcass detection. However, data from concurrent aerial redd and carcass surveys over several spawning seasons are not available for the lower Feather River. Therefore, for the purpose of this analysis, it was assumed that a three-week interval occurred between the initiation of spawning (redd construction) and the observation of the adult carcasses, based on the information derived from literature, and on the analysis of the lower American River data.

In the LFC during 2002, an estimated 0.05 percent of all spawning occurred during July, and 2.9 percent in August. In the HFC, percentage of all spawning was 0.04 percent in June, 0.28 percent in July and 1.83 percent in August of 2002. In contrast, DWR biologists did not observe redds in the lower Feather River in mid August. Nonetheless, lack of detection of redds early in the spawning season does not necessarily imply lack of spawning. Carcasses were discovered on the first day of the carcass survey, so salmon could have spawned prior to initiation of the surveys. Carcass survey data indicate that a very low proportion of the population spawns in the beginning of the season. The low percentages of modeled spawning distributions in the LFC and HFC suggest that it would have been unlikely for redds to be detected unless very intensive surveys had been conducted.

4.2.4 Estimation of Adult Pre-spawning Temporal Distribution

It is assumed that adult fall-run Chinook salmon spend two weeks in the spawning reach prior to the onset of spawning (USBR 1994), therefore the temporal distribution of pre-spawning Chinook salmon mimics the temporal distribution of spawning, lagged backward by two weeks. Figure 4.2-4 shows the temporal distributions of pre-spawning Chinook salmon in the LFC and HFC of the lower Feather River in 2002.

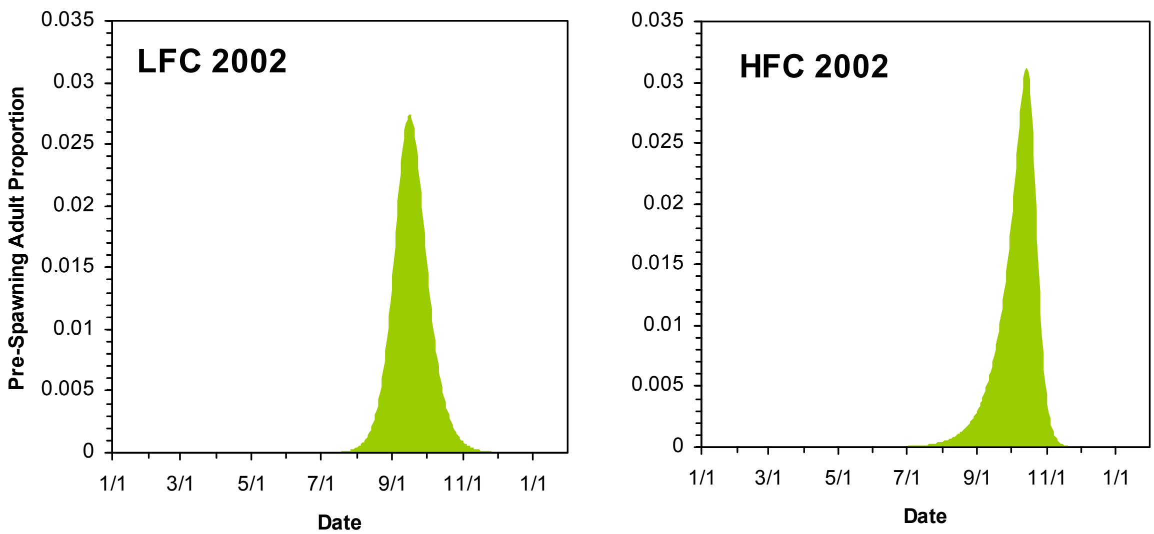

Figure 4.2-4. The estimated daily pre-spawning distributions of Chinook salmon in the LFC and HFC of the lower Feather River during 2002.

Peaks in the estimated pre-spawning distributions occurred on September 16 and October 15, 2002 in the LFC and HFC, respectively.

4.2.5 Water Temperature Data as Input Variable for The USBR Chinook Salmon Water Temperature Mortality Model

In 2002 and 2003, water temperatures were recorded with data loggers located at 26 sites along the Feather and Sacramento River (Figure 4.1-1). Twelve of these sites were located in the LFC, and five were located in the HFC. Seven sites were located on the lower Feather River downstream of Gridley Bridge, and the remaining two sites were located in the Sacramento River at and near the mouth of the Feather River.

The data loggers recorded daily mean water temperatures from February 2, 2002 to February 10, 2004. However, not all loggers operated continuously during this period. Thus, while some days, (e.g., in February and March, 2002) as little as two data loggers were operating, other days as many as 24 data loggers were recording water temperatures. The lack of exact correspondence between the location of the data loggers and the location and dimension of the USBR Chinook salmon water temperature mortality model reaches, and the lack of continuous series of daily mean water temperature records for each logger location during the study period lead to the processing of the available daily mean water temperature records to produce nine series of average mean water temperatures, one for each model reach (Table 4.1-3). The resulting nine data series were continuous within the period from February 2, 2002 to February 10, 2004.

4.2.6 Spatial Pattern of Water Temperature

Because of the gaps in daily water temperature records, a spatial modeling approach was undertaken to estimate the missing data of the daily water temperature records. When the 735 series of daily mean water temperatures recorded by the data loggers operating each day were plotted against the river mile of the data logger locations, they displayed a consistent spatial pattern of water temperatures increasing from upstream towards the downstream locations, eventually approaching an asymptotic (i.e., relatively the same value) water temperature (Figure 4.2-5). In spring and summer, in particular, daily mean water temperature appeared to increase rapidly over the first upstream river miles, with diminished water temperature increases as the logger location approaches the confluence of the Feather and Sacramento rivers. During autumn and winter, water temperatures remained comparatively similar throughout the river reaches, even though less pronounced asymptotic spatial patterns were still present.

The water temperature data modeling procedure consisted of the following steps:

1) Fitting an asymmetric logistic curve to each of the 735 series of daily mean water temperatures recorded by the loggers operating each day;
2) Estimating mean daily water temperatures at each river mile from RM 67 to RM 0, for each day in the period February 2, 2002 to February 10, 2004, using the estimated parameters obtained in the previous step; and
3) Averaging the estimated mean daily water temperatures per river mile within each of the nine model reaches.

Asymmetric logistic models were fit to the water temperature data because, among several models tried, the asymmetric logistic model provided the smallest mean square error. Model fitting was accomplished through the minimization of the sum of the squared differences between observed and predicted values (i.e., non-linear least-squares). Thus, for each of the 735 series of daily mean water temperatures recorded by the loggers operating each day, the following equation was fit using nonlinear least squares:

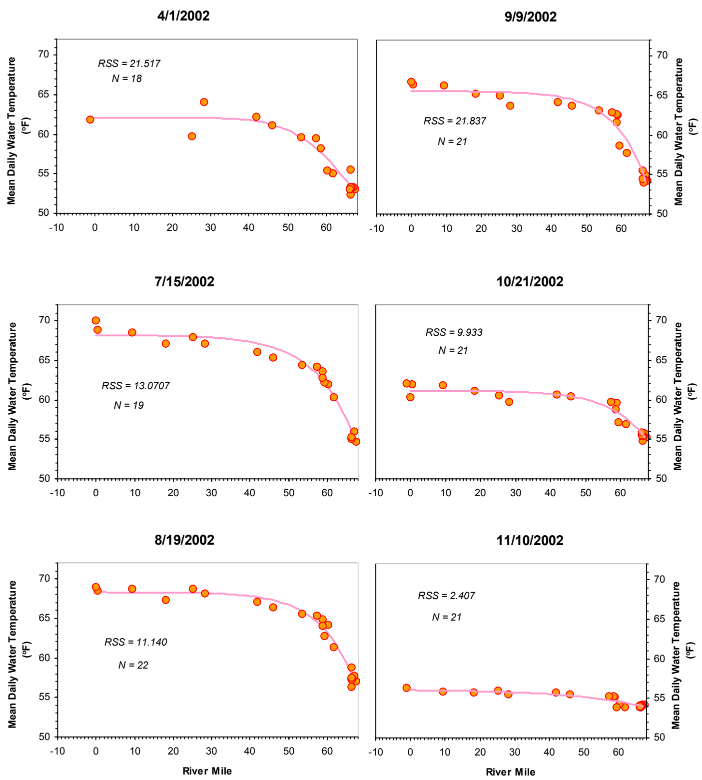

Figure 4.2-5. Fitted asymmetric logistic curves (lines), and mean daily water temperatures (circles) available from data loggers operating at 6 selected dates during 2002 as function of river mile in the Feather River.

Note: RSS indicates the residual sum of squares of the nonlinear least square fit, and N indicates the number of data loggers operating on the selected date.

$$T_{j,i}\left({}^{o}F\right) = \alpha_{o,i} - \frac{\alpha_{o,i}}{\left(1+\exp\left(\beta_{o,i}+\beta_{1,i}\times RM_{j,i}\right)\right)^{1/\delta_i}},$$

Where,

$T_{j,i}$ is the daily mean water temperature predicted for each logger and day;

$\alpha_{o,i}$ is the asymptotic value towards which water temperatures will tend to approach on day "i";

$\beta_{o,i}$ is the logistic parameter corresponding to the intercept;

$\beta_{1,i}$ is the logistic parameter corresponding to the slope;

δ_i is the logistic parameter that controls the symmetry of the resulting curve (if δ_i = 1 the curve is the typical symmetrical logistic); and

$RM_{j,i}$ is the river mile location of data logger "*j*" operating in day "*i*" (*i* = {1,2,...,735}).

Figure 4.2-5 illustrates the mean daily water temperatures available from water temperature data loggers operating at six selected dates during 2002, and the curves resulting from fitting asymmetric logistic curves to these data. It also depicts observed spatial pattern of water temperature as function of river mile as the season progresses from spring towards winter.

4.2.7 Estimation Of Daily Mean Water Temperatures By Reach

Once the fitted asymmetric logistic curves were obtained for each of the 735 series of daily mean water temperatures expressed as function of river mile, the resulting curves were used to estimate mean daily water temperatures per river mile from RM 67 to RM 0, for every day during the period February 2, 2002 to February 10, 2004. Finally, the estimated mean daily water temperatures were grouped into nine reaches of the lower Feather River, and an average daily water temperature was calculated for each reach. The mean water temperature values, which were used as input to the USBR Chinook salmon water temperature mortality model, are shown in Appendix B, and illustrated in Figure 4.2-6.

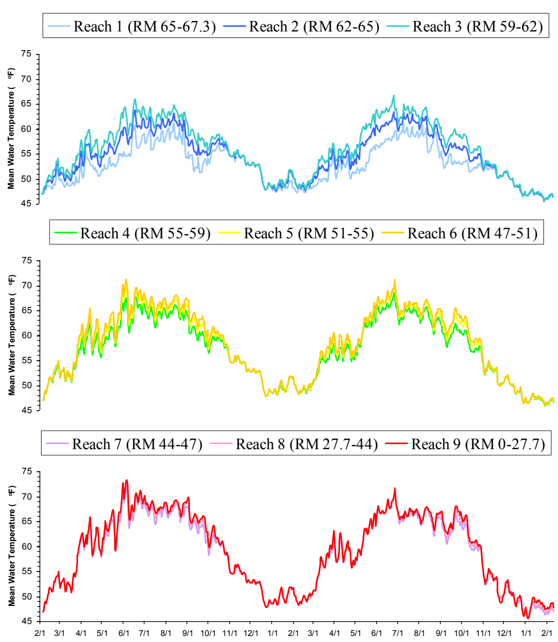

Figure 4.2-6. Estimated daily mean water temperatures by river reach from February 2, 2002 to February 10, 2004 in the lower Feather River.

5.0 STUDY RESULTS

5.1 ESTIMATED PERCENTAGE OF CHINOOK SALMON EGGS AND ALEVIN LOSSES DUE TO WATER TEMPERATURE INDUCED MORTALITY

Figure 5.1.1 depicts the estimated daily percent losses of eggs in adults (*in vivo* egg mortality), eggs in redds (egg mortality) and pre-emergent fry (pre-emergent fry mortality) of Chinook salmon in the lower Feather River (i.e., LFC and HFC) during the 2002/2003 spawning and incubation period. Daily mortality occurred on days with average water temperatures above 55ºF. Both the *in vivo* egg mortality and the egg mortality show at least two clear peaks. The first peak corresponds to the third quarter of September, and the second peak corresponds to mid-October.

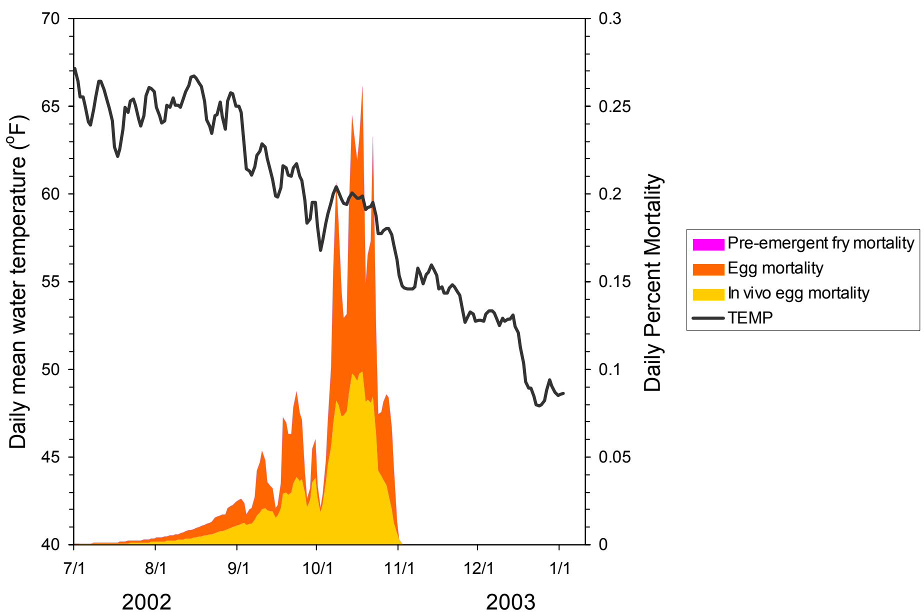

Figure 5.1-1. Daily percent losses of eggs in adults, eggs in redds and pre-emergent-fry (alevin) of Chinook salmon in the lower Feather River during the 2002/2003 spawning and incubation period.

By summing the daily percent losses depicted in Figure 5.1-1, 16.3 percent of all Chinook salmon eggs and alevins were estimated to have been lost due to water temperature-induced mortality during the 2002/2003 spawning and incubation period over the entire lower Feather River. Of the total egg and alevin mortality (16.3 percent in the lower Feather River), 10.6 percent of the total mortality occurred in the LFC and 5.7 percent of the total egg and alevin mortality associated with water temperature occurred in the HFC (Figure 5.1-2).

The 16.3 percent annual total mortality for the entire lower Feather River was composed of:

- 7.9 percent water temperature-induced *in vivo* egg mortality (5.2 percent and 2.7 percent occurred in the LFC and HFC, respectively);
- 8.4 percent water temperature-induced egg mortality in redds (5.4 percent and 3 percent occurred in the LFC and HFC, respectively); and
- 0.033 percent water temperature-induced alevin mortality (0.033 percent and 0 percent occurred in the LFC and HFC, respectively).

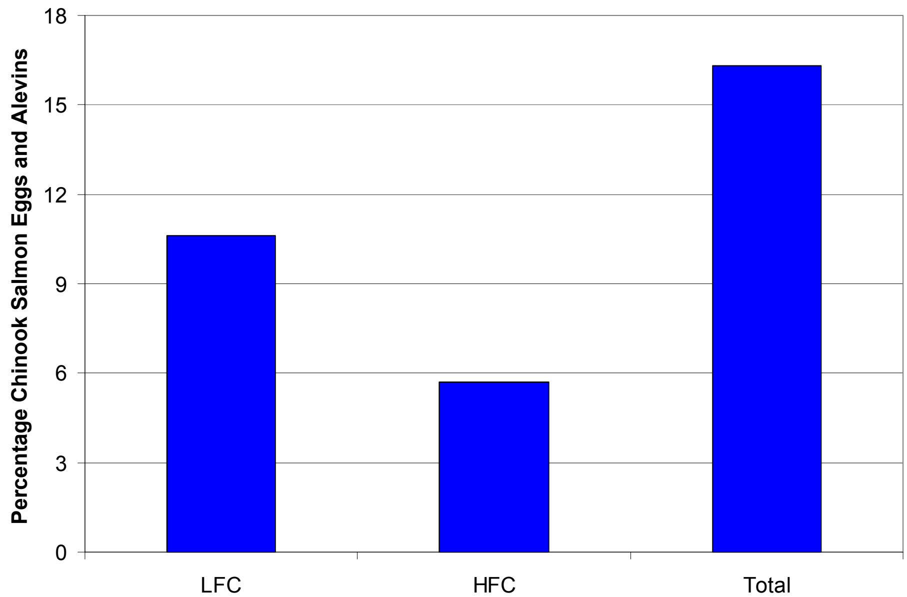

Figure 5.1-2. Percentage of Chinook salmon eggs and alevin losses due to water temperature-induced mortality in the LFC and HFC of the lower Feather River during the 2002/2003 spawning and incubation season.

Figures 5.1-3 and 5.1-4 depict the breakdown of the 16.3 percent annual total water temperature-induced mortality for the entire lower Feather River for eggs *in vivo*, incubating eggs, and alevins by month and reach (LFC and HFC).

The highest percentage of egg and alevin losses due to water temperature-induced mortality in the Feather River occurred in October, when 5.4 percent out of a total mortality of 10.6 percent occurred in the LFC and 4 percent out of 5.7 percent total mortality occurred in the HFC. In September, 3.4 percent of the total mortality occurred in the LFC, and 1.3 percent in the HFC. These high mortality proportions are likely to be linked to the peaks in spawning distribution in each reach.

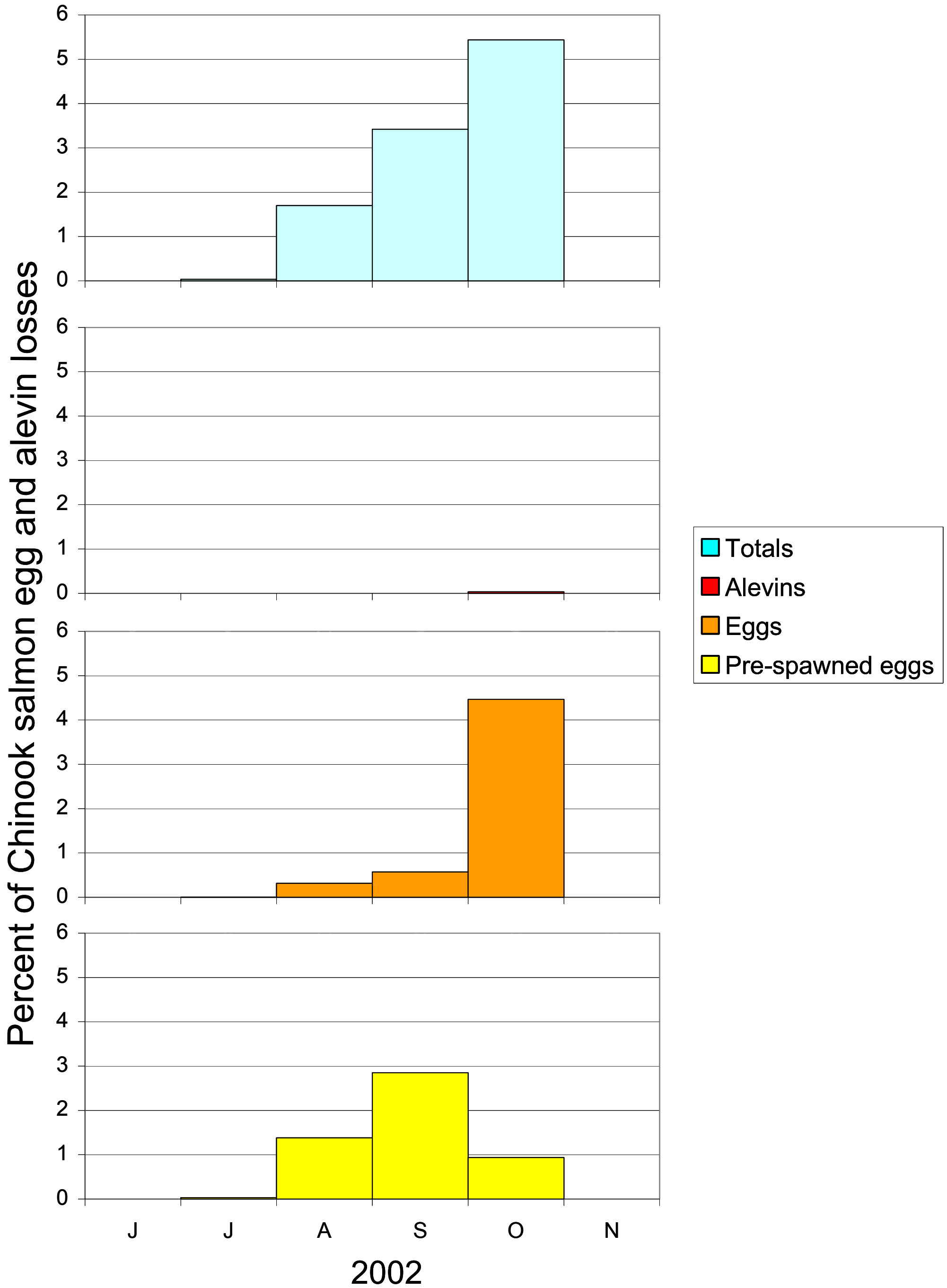

Figure 5.1-3. Percentage of Chinook salmon eggs and alevin losses due to water temperature-induced mortality in the LFC of the lower Feather River during the 2002/2003 spawning.

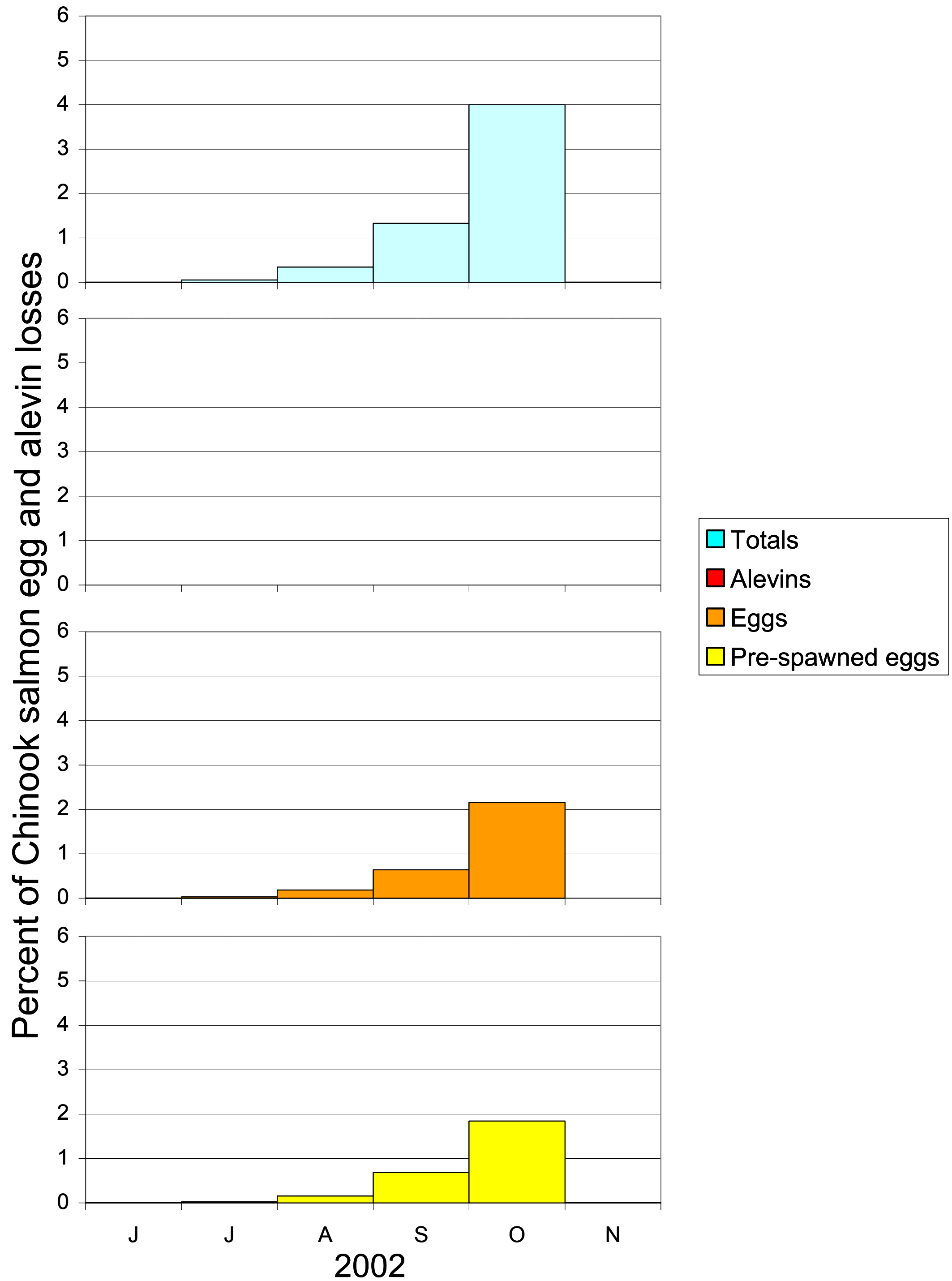

Figure 5.1-4. Percentage of Chinook salmon eggs and alevin losses due to water temperature-induced mortality in the HFC of the lower Feather River during the 2002/2003 spawning and incubation season.

6.0 ANALYSES

6.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

Task 2C is a subtask of SP-F10, *Evaluate the timing, magnitude and frequency of water temperatures and their effects on Chinook salmon egg and alevin survival.* Task 2C fulfills a portion of the FERC application requirements by evaluating the potential for, and the impact from, the percent losses of Chinook salmon eggs and alevins due to water temperature induced mortality in the lower Feather River. Additionally, data collected for this task could serve as a foundation for future evaluation and development of potential Resource Actions.

During the 2002 Chinook salmon spawning and incubation seasons, DWR conducted Chinook salmon carcass survey in the lower Feather River. Studies were utilized to estimate potential spawning distributions used in the USBR Chinook salmon water temperature mortality model. During this period, data loggers were utilized to record water temperatures in different stations. The incidence of water temperature induced mortality in the 2002 spawning and incubation seasons was used to determine Chinook salmon losses as a proportion of the total number of eggs and alevins in the river.

6.2 PROJECT RELATED EFFECTS

An estimated 16.3 percent early life stage mortality for the entire lower Feather River occurred during the 2002/2003 spawning and incubation period. This total-river mortality estimate was divided by reach based on the different temporal pre-spawning and spawning distributions observed in the LFC and HFC. The USBR Chinook salmon water temperature mortality model distributed the pre-spawning (PSD) and spawning (SD) distributions (Figures 4.2-3 and 4.2-4) into nine reaches, three in the LFC and six in the HFC (Table 4.1.3). The model subjected these reach-specific distributions to the nine reach-specific water temperature conditions (Figure 4.2-6) to estimate the corresponding losses of Chinook salmon eggs and alevins. Of the total estimated water temperature-induced early life stage mortality in the entire lower Feather River during the 2002/2003 spawning and incubation period, 10.6 percent occurred in the LFC, and 5.7 percent occurred in the HFC.

Early life stage water temperature-induced mortalities were estimated for various runs of Chinook salmon in the recent BA conducted for the CVP and SWP OCAP using the USBR model (USBR 2004). In the OCAP BA, early life stage mortalities were estimated for fall-run and spring-run Chinook salmon in the Sacramento River, and for fall-run Chinook salmon in the lower American River, rivers proximate to the lower Feather River. Results of this study (SP-F10 Task 2C) were compared to the OCAP BA early life stage mortality estimates for general comparative purposes. In the OCAP BA, the long-term average mortality rate for fall-run Chinook salmon under existing conditions was estimated to be 14.5 percent in the lower American River. Furthermore, in the

Sacramento River, the long-term average mortality rate for fall-run Chinook salmon was estimated to be 13.2 percent, and spring-run Chinook salmon mortality was estimated to be 20.8 percent at Balls Ferry, and 26.5 percent at Bend Bridge and Jelly's Ferry.

The 16.3 percent Chinook salmon early life stage mortality rate estimated in this report for the lower Feather River is within the range of the recent estimates in the OCAP BA (USBR 2004) for spring-run and fall-run Chinook salmon in the Sacramento River, and fall-run Chinook salmon in the lower American River.

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State of California
The Resources Agency
Department of Water Resources

FINAL REPORT
EVALUATION OF THE TIMING, MAGNITUDE AND FREQUENCY OF WATER TEMPERATURES AND THEIR EFFECTS ON CHINOOK SALMON EGG AND ALEVIN SURVIVAL
SP-F10, TASK 2C

OROVILLE FACILITIES RELICENSING
FERC PROJECT NO. 2100

APPENDIX A
FORTRAN CODE OF THE MODIFIED USBR CHINOOK SALMON WATER TEMPERATURE MORTALITY MODEL FOR THE FEATHER RIVER

JUNE 2004

```
      PROGRAM SALFRC
C     MODIFIED 3/30/2004 BY K. VODOPALS, SURFACE WATER RESOURCES, INC.
C     PROGRAM SALMONF(INPUT,OUTPUT,TAPE1,TAPE2,TAPE4)
      DIMENSION T(365,9,4),TR(911,9),EM(911,9),FM(911,9),
     +RD(9,4),EC(8),FC(6),AD(911,4),ESD(911,4),FRY(911,4),
     +EFRY(911,4),SKIL(9,4),ED(911,4),FD(911,4),AKIL(911,4),
     +EKIL(911,4),FKIL(911,4),TAKIL(911,4),TEKIL(911,4),
     +TFKIL(911,4),CAK(4),CEK(4),CFK(4),TOTKIL(4),TOTMKIL(30,4),
     +AT(12,8),ATAKIL(30,4),ATEKIL(30,4),JULB(30),JULE(30),CEFRY(4),
     +SD(911,4),ATFKIL(30,4),PSC(11),PSM(911,9),TOTEFRY(2),TEFRY(911,4),
     +PSD(911,4),IYR(2),NAME(4),ATK(4),TO(12,7,100),MONTH(30)
      CHARACTER*10 NAME
      CHARACTER*8 MONTH
      DATA PSC/.0,.00034,.00171,.00351,.00540,.00783,.01135,.01581,
     +.02094,.02627,.03348/
      DATA EC/.00347,.00736,.01428,.05613,.10174,
     +.31871,.34207,.48205/
      DATA FC/.00750,.02034,.04830,.09428,.28031,.36904/
      DATA JULB/1,32,60,91,121,152,182,213,244,274,305,335,366,397,425,
     +456,486,517,547,578,609,639,670,700,731,762,791,822,852,883/
      DATA JULE/31,59,90,120,151,181,212,243,273,304,334,365,396,424,
     +455,485,516,546,577,608,638,669,699,730,761,792,821,851,882,911/
      DATA (RD(I,1),I=1,9)/.27905,.380025,.152036,0.,0.,0.,0.,        LFC 2002
     +0.,0./
      DATA (RD(I,2),I=1,9)/0.,0.,0.,.12201,.066879,0.,                HFC 2002
     +0.,0.,0./
      DATA (RD(I,3),I=1,9)/.366919,.278602,.104561,0.,0.,0.,0.,       LFC 2003
     +0.,0./
      DATA (RD(I,4),I=1,9)/0.,0.,0.,.161399,.088519,0.,               HFC 2003
     +0.,0.,0./
      DATA IYR/2002,2003/

      OPEN(1,FILE='SALNAMF')
      OPEN(2,FILE='smfrloss')
      OPEN(4,FILE='smfrsalt')
      OPEN(5,FILE='prespawn')
      OPEN(6,FILE='spawn')
      OPEN(7,FILE='MONTHS')

 50   FORMAT(11X,F5.2,F11.2)
906   FORMAT(1X,4A10)
907   FORMAT(30A8)
473   FORMAT(1X,I5,2X,12F9.1)
472   FORMAT(16X,I4,F13.5,8F16.5)             !Format for daily temp file
```

```
 471  FORMAT(16X,I4,F13.6,3F16.6)         !Format for spawning and pre-spawning
distributions
      NYR=2
      READ(1,906)(NAME(I),I=1,4)
      READ(7,907)(MONTH(Q),Q=1,30)
C
C      READ IN DAILY TEMPERATURES
C
       READ (*,*)
       N=911
       DO 10 I=1,N
       READ (*,472) N,(TR(I,J), J = 1,9)
  10   CONTINUE
C
C      READ IN PRE-SPAWNING AND SPAWNING DISTRIBUTIONS
C
       READ(5,*)
       READ(6,*)
       N=911
       DO 11 I=1,N
       READ(5,471) N,(PSD(I,K),K=1,4)                    !K=1,2 is for 2002 and K=3,4 is for
2003
       READ(6,471) N,(SD(I,K),K=1,4)
  11   CONTINUE
C      DO 13 K=1,4                          !DEBUG
C      DO 12 I=1,911                        !DEBUG
C       IF(PSD(I,K).EQ.SD(I,K)) THEN                    !DEBUG
C          WRITE(*,*)I,PSD(I,K),SD(I,K),J,K                !DEBUG
C       END IF                              !DEBUG
C  12  CONTINUE                              !DEBUG
C  13  CONTINUE                              !DEBUG
C
C           COMPUTE PRESPAWNING MORTALITIES
C
      DO 400 NY=1,NYR
      IF (NY.eq.1) N1=1
      IF (NY.eq.2) N1=456
      DO 80 I=N1,N1+455
      DO 81 J=1,9
      IF(TR(I,J).LE.52.)GO TO 90
      IF(TR(I,J)-53.)82,82,83
  82  PSM(I,J)=PSC(2)-(53.-TR(I,J))*PSC(2)
      GO TO 81
  83  IF(TR(I,J)-54.)84,84,85
```

```
  84  PSM(I,J)=PSC(3)-(54.-TR(I,J))*(PSC(3)-PSC(2))
      GO TO 81
  85  IF(TR(I,J)-55.)86,86,87
  86  PSM(I,J)=PSC(4)-(55.-TR(I,J))*(PSC(4)-PSC(3))
      GO TO 81
  87  IF(TR(I,J)-56.)88,88,89
  88  PSM(I,J)=PSC(5)-(56.-TR(I,J))*(PSC(5)-PSC(4))
      GO TO 81
  89  IF(TR(I,J)-57.)91,91,92
  91  PSM(I,J)=PSC(6)-(57.-TR(I,J))*(PSC(6)-PSC(5))
      GO TO 81
  92  IF(TR(I,J)-58.)93,93,94
  93  PSM(I,J)=PSC(7)-(58.-TR(I,J))*(PSC(7)-PSC(6))
      GO TO 81
  94  IF(TR(I,J)-59.)96,96,97
  96  PSM(I,J)=PSC(8)-(59.-TR(I,J))*(PSC(8)-PSC(7))
      GO TO 81
  97  IF(TR(I,J)-60.)98,98,95
  98  PSM(I,J)=PSC(9)-(60.-TR(I,J))*(PSC(9)-PSC(8))
      GO TO 81
  99  IF(TR(I,J)-61.)101,101,95
 101  PSM(I,J)=PSC(10)-(61.-TR(I,J))*(PSC(10)-PSC(9))
      GO TO 81
  90  PSM(I,J)=0.
      GO TO 81
  95  IF(TR(I,J).GE.62.)GO TO 65
      PSM(I,J)=PSC(10)+(TR(I,J)-61.)*(PSC(11)-PSC(10))
      GO TO 81
  65  PSM(I,J)=PSC(11)
  81  CONTINUE
  80  CONTINUE
C
C        COMPUTE EGG MORTALITIES
C
      DO 33 I=N1,N1+455
      DO 34 J=1,9
      IF(TR(I,J).LE.56.)GO TO 23
      GO TO 24
  23  EM(I,J)=0.
      GO TO 34
  24  IF(TR(I,J)-57.)35,35,36
  35  EM(I,J)=EC(1)-(57.-TR(I,J))*EC(1)
      GO TO 34
  36  IF(TR(I,J)-58.)37,37,38
```

```
 37  EM(I,J)=EC(2)-(58.-TR(I,J))*(EC(2)-EC(1))
     GO TO 34
 38  IF(TR(I,J)-59.)39,39,40
 39  EM(I,J)=EC(3)-(59.-TR(I,J))*(EC(3)-EC(2))
     GO TO 34
 40  IF(TR(I,J)-60.)41,41,42
 41  EM(I,J)=EC(4)-(60.-TR(I,J))*(EC(4)-EC(3))
     GO TO 34
 42  IF(TR(I,J)-61.)43,43,44
 43  EM(I,J)=EC(5)-(61.-TR(I,J))*(EC(5)-EC(4))
     GO TO 34
 44  IF(TR(I,J)-62.)45,45,46
 45  EM(I,J)=EC(6)-(62.-TR(I,J))*(EC(6)-EC(5))
     GO TO 34
 46  IF(TR(I,J)-63.)47,47,48
 47  EM(I,J)=EC(7)-(63.-TR(I,J))*(EC(7)-EC(6))
     GO TO 34
 48  IF(TR(I,J)-64.)49,49,1
 49  EM(I,J)=EC(8)-(64.-TR(I,J))*(EC(8)-EC(7))
     GO TO 34
  1  EM(I,J)=EC(8)
     IF(EM(I,J).GT.1.)EM(I,J)=1.
 34  CONTINUE
 33  CONTINUE
C
C        COMPUTE FRY MORTALITIES
C
     DO 51 I=N1,N1+455
     DO 52 J=1,9
100  IF(TR(I,J).LE.58.)GO TO 25
     GO TO 26
 25  FM(I,J)=0.
     GO TO 52
 26  IF(TR(I,J)-59.)53,53,54
 53  FM(I,J)=FC(1)-(59.-TR(I,J))*FC(1)
     GO TO  52
 54  IF(TR(I,J)-60.)55,55,56
 55  FM(I,J)=FC(2)-(60.-TR(I,J))*(FC(2)-FC(1))
     GO TO 52
 56  IF(TR(I,J)-61.)57,57,58
 57  FM(I,J)=FC(3)-(61.-TR(I,J))*(FC(3)-FC(2))
     GO TO 52
 58  IF(TR(I,J)-62.)59,59,60
 59  FM(I,J)=FC(4)-(62.-TR(I,J))*(FC(4)-FC(3))
```

```
      GO TO 52
   60  IF(TR(I,J)-63.)61,61,62
   61  FM(I,J)=FC(5)-(63.-TR(I,J))*(FC(5)-FC(4))
      GO TO 52
   62  IF(TR(I,J).GE.64.)GO TO 63
      FM(I,J)=FC(6)-(64.-TR(I,J))*(FC(6)-FC(5))
      GO TO 52
   63  FM(I,J)=FC(6)
      IF(FM(I,J).GT.1.)FM(I,J)=1.
   52  CONTINUE
   51  CONTINUE
C
C             ADULT DISTRIBUTION AND PRESPAWNING LOSSES
C
      IF (NY.eq.1) then
         K1=1
         K2=2
      ELSE
         K1=3
         K2=4
      ENDIF
      DO 130 K=K1,K2
      DO 131 I=N1,N1+455
      TAKIL(I,K)=0.
      TEKIL(I,K)=0.
      TFKIL(I,K)=0.
  131  CONTINUE
  130  CONTINUE
      DO 900 J=1,9
      DO 140 K=K1,K2
      DO 141 I=N1,N1+455
      AD(I,K)=0.
      ESD(I,K)=0.
      FRY(I,K)=0.
      ED(I,K)=0.
      EFRY(I,K)=0.
      FD(I,K)=0.
      AKIL(I,K)=0.
      EKIL(I,K)=0.
      FKIL(I,K)=0.
  141  CONTINUE
  140  CONTINUE
      DO 200 K=K1,K2
      DO 202 I=N1,N1+455
```

```
C     IF(I-1)204,204,205
      IF(I-1)204,204,205
 204  AD(I,K)=(PSD(I,K)-SD(I,K))*RD(J,K)
      IF(AD(I,K).LT.0) THEN
c         AD(I,K)=(PSD(I,K)-(SD(I,K)-PSD(I,K)))*RD(J,K)
C         AD(I,K)=PSD(I,K)*RD(J,K)
C     WRITE(*,*)I,AD(I,K),J,K                          !DEBUG
         AD(I,K)=0
C     WRITE(*,*)I,AD(I,K),J,K                          !DEBUG
      END IF
      AKIL(I,K)=AD(I,K)*PSM(I,J)
      AD(I,K)=AD(I,K)-AKIL(I,K)
C     write(*,*)I,AD(I,2),AKIL(I,2),K,J                        !DEBUG
      GO TO 202
 205  AD(I,K)=AD(I-1,K)+(PSD(I,K)-SD(I,K))*RD(J,K)
      IF(AD(I,K).LT.0) THEN
c         AD(I,K)=AD(I-1,K)+(PSD(I,K)-(SD(I,K)-PSD(I,K)))*RD(J,K)
C         AD(I,K)=AD(I-1,K)+PSD(I,K)*RD(J,K)
C         AD(I,K)=PSD(I,K)*RD(J,K)
      WRITE(*,*)I,AD(I,K),J,K                          !DEBUG
         AD(I,K)=0
C     WRITE(*,*)I,AD(I,K),J,K                          !DEBUG
      END IF
      AKIL(I,K)=AD(I,K)*PSM(I,J)
      AD(I,K)=AD(I,K)-AKIL(I,K)
C     write(*,*)I,AD(I,K),K,J                          !DEBUG
 202  CONTINUE
 200  CONTINUE
C     DO 674  K=1,4
C     DO 675 II=1,911                                  !debug
C         write(*,*)II , AD(II,K), J, K             !debug
C 675  CONTINUE
C 674  CONTINUE                                        !debug
C
C        EGG SPAWNING DISTRIBUTION ADJUSTED FOR PRESPAWNING LOSSES
C
      DO 150 K=K1,K2
      DO 151 I=N1,N1+455
C     ESD(I,K)=(SD(I,K)-PSD(I,K))*RD(J,K)
C     ESD(I,K)=SD(I,K)*RD(J,K)
C     IF(ESD(I,K).LT.0) THEN
C         ESD(I,K)=(SD(I,K)-(PSD(I,K)-SD(I,K)))*RD(J,K)
          ESD(I,K)=SD(I,K)*RD(J,K)
C          ESD(I,K)=0
```

```
C     END IF
C     WRITE(*,*)I,ESD(I,K),J,K
 151  CONTINUE
 150  CONTINUE
      DO 152 K=K1,K2
      DO 153 I=N1,N1+455
      IF(AKIL(I,K).EQ.0.)GO TO 153
      N=I+1
      IF(N.EQ.N1+456)GO TO 152
 157  IF(ESD(N,K).EQ.0.)GO TO 155
      ESD(N,K)=ESD(N,K)-AKIL(I,K)
C     IF(N-I.GT.12) THEN
C        WRITE(*,*)N,I
C     END IF
 156  IF(ESD(N,K).GE.0.)GO TO 153
      ESD(N+1,K)=ESD(N+1,K)+ESD(N,K)
      ESD(N,K)=0.
C     write(*,*)N,I,ESD(N,2),AKIL(I-1,2),K,J                !debug
      N=N+1
      IF(N.EQ.N1+456)GO TO 162
      GO TO 156
 155  N=N+1
C     WRITE(*,*)N,I,ESD(I,K),AKIL(I,K)
      IF(N.EQ.N1+456)GO TO 152
      GO TO 157
 162  IF(ESD(N,K).LT.0.)ESD(N,K)=0.
C     write(*,*)N,I,ESD(N,2),AKIL(I-1,2),K,J                !debug
 153  CONTINUE
 152  CONTINUE
C     DO 674  K=1,2
C     DO 675 II=1,456                                     !debug
C        write(*,*)II , ESD(II,K),AKIL(II,K), J, K          !debug
C 675  CONTINUE
C 674  CONTINUE                                            !debug
C
C           PRE-EMERGENT FRY DEVELOPMENT
C
      DO 230 K=K1,K2
      DO 232 I=N1,N1+455
      IF(ESD(I,K).EQ.0.)GO TO 232
      CTU=0.
      DO 233 L=N1,N1+455
      II=L+I-1
      IF(II.GT.N1+455)GO TO 236
```

```
      CTU=CTU+TR(II,J)-32.
      IF(CTU-750.)233,235,235
 233  CONTINUE
      FRY(II,K)=0.
      GO TO 232
 235  FRY(II,K)=ESD(I,K)+FRY(II,K)
C          WRITE(*,*)II,I,K
C        write (*,*)CTU,FRY(II,K),I,J,II,K     !debug
      GO TO 232
 236  DO 237 M=I,911
      CTU=CTU+TR(M,J)-32.
C     WRITE(*,*)M,CTU,J,K
      IF(CTU-750.)237,238,238
 237  CONTINUE
      FRY(M,K)=0.
      GO TO 232
 238  FRY(M,K)=ESD(I,K)+FRY(M,K)
C        write (*,*)ESD(I,K),FRY(M,K),I,J,K     !debug
 232  CONTINUE
 230  CONTINUE
C
C           EGG DISTRIBUTION AND LOSSES
C                                      !Start the egg distributions one day prior to the SD
      DO 240 K=K1,K2                   !Start of spawning distributions (day):
      IF(K.EQ.1)N2=195                 !July 15 (196)= LFC 2002
      IF(K.EQ.2)N2=169                 !June 19 (170)= HFC 2002
      IF(K.EQ.3)N2=557                 !July 12 (558)= LFC 2003
      IF(K.EQ.4)N2=520                 !June 5  (521)= HFC 2003
      DO 242 I=N2,N1+455
      ED(I,K)=ESD(I,K)+ED(I-1,K)-FRY(I,K)
      IF(ED(I,K).LT.0.)ED(I,K)=0.
      EKIL(I,K)=ED(I,K)*EM(I,J)
      ED(I,K)=ED(I,K)-EKIL(I,K)
      N=I+1
      IF(N.EQ.N1+456)N=1
      IF(N.EQ.N2)GO TO 256
 253  IF(FRY(N,K).EQ.0.)GO TO 254
      FRY(N,K)=FRY(N,K)-EKIL(I,K)
 248  IF(FRY(N,K).GE.0.)GO TO 256
      IF(N.EQ.N1+455)GO TO 249
      FRY(N+1,K)=FRY(N+1,K)+FRY(N,K)
      FRY(N,K)=0.
      N=N+1
      IF(N.EQ.N2)GO TO 245
```

```
      GO TO 248
 249  FRY(N1+456,K)=FRY(N1+456,K)+FRY(N1+455,K)
      FRY(N1+455,K)=0.
      N=N1
      GO TO 248
 254  N=N+1
      IF(N.EQ.N1+456)GO TO 240
      IF(N.EQ.N2)GO TO 256
      GO TO 253
 245  FRY(N,K)=0.
 256  IF(I.EQ.N1+455)GO TO 244
      GO TO 242
 244  DO 246 M=N1,N1+455
      IF(SD(M,K).GT.0.)GO TO 242
      IF(M.GT.N1)GO TO 247
      ED(M,K)=ED(N1+455,K)-FRY(M,K)
      IF(ED(M,K).LT.0.)ED(M,K)=0.
      IF(ED(M,K).EQ.0.)GO TO 242
      EKIL(M,K)=ED(M,K)*EM(M,J)
      ED(M,K)=ED(M,K)-EKIL(M,K)
      GO TO 255
 247  ED(M,K)=ED(M-1,K)-FRY(M,K)
      IF(ED(M,K).LT.0.)ED(M,K)=0.
      IF(ED(M,K).EQ.0.)GO TO 242
      EKIL(M,K)=ED(M,K)*EM(M,J)
      ED(M,K)=ED(M,K)-EKIL(M,K)
 255  N=M+1
      IF(N.EQ.N2)GO TO 242
 273  IF(FRY(N,K).EQ.0.)GO TO 274
      FRY(N,K)=FRY(N,K)-EKIL(M,K)
 258  IF(FRY(N,K).GE.0.)GO TO 246
      FRY(N+1,K)=FRY(N+1,K)+FRY(N,K)
      FRY(N,K)=0.
      N=N+1
      IF(N.EQ.N2)GO TO 243
      GO TO 258
 274  N=N+1
      IF(N.EQ.N2)GO TO 246
      GO TO 273
 243  FRY(N,K)=0.
 246  CONTINUE
 242  CONTINUE
 240  CONTINUE
C     DO 674 K=1,2
```

```
C     DO 675 II=1,456                          !debug
C         write(*,*)II, EKIL(II,K),FRY(II,K), J, K  !debug
C 675  CONTINUE
C 674  CONTINUE                                       !debug
C
C       EMERGENT FRY DEVELOPMENT
C
      DO 260 K=K1,K2
      DO 262 I=N1,N1+455
      IF(FRY(I,K).EQ.0.)GO TO 262
      CTU=0.
      DO 263 L=N1,N1+455
      II=L+I-1
      IF(II.GT.N1+455)GO TO 266
      CTU=CTU+TR(II,J)-32.
      IF(CTU-750.)263,265,265
 263  CONTINUE
      EFRY(II,K)=0.
      GO TO 262
 265  EFRY(II,K)=FRY(I,K)+EFRY(II,K)
      GO TO 262
 266  DO 267 M=I,911
      CTU=CTU+TR(M,J)-32.
      IF(CTU-750.)267,268,268
 267  CONTINUE
      IF(M.GT.911)GO TO 260
      EFRY(M,K)=0.
      GO TO 262
 268  EFRY(M,K)=FRY(I,K)+EFRY(M,K)
 262  CONTINUE
 260  CONTINUE
C
C        PRE-EMERGENT FRY DISTRIBUTION AND LOSSES
C
      DO 280 K=K1,K2
      IF(K.EQ.1)N2=195                          !Same idea as for egg distribution
      IF(K.EQ.2)N2=169
      IF(K.EQ.3)N2=557
      IF(K.EQ.4)N2=520
      DO 282 I=N2,N1+455
      FD(I,K)=FRY(I,K)+FD(I-1,K)-EFRY(I,K)
c     WRITE(*,*)I, FD(I,K), J, K
      IF(FD(I,K).LT.0.)FD(I,K)=0.
      FKIL(I,K)=FD(I,K)*FM(I,J)
```

```
C     WRITE(*,*)FKIL(I,K), J, K                    !DEBUG
      FD(I,K)=FD(I,K)-FKIL(I,K)
      N=I+1
      IF(N.EQ.N1+456)N=1
      IF(N.EQ.N2)GO TO 356
 353  IF(EFRY(N,K).EQ.0.)GO TO 354
      EFRY(N,K)=EFRY(N,K)-FKIL(I,K)
 348  IF(EFRY(N,K).GE.0.)GO TO 356
      IF(N.EQ.N1+455)GO TO 349
      EFRY(N+1,K)=EFRY(N+1,K)+EFRY(N,K)
      EFRY(N,K)=0.
      N=N+1
      IF(N.EQ.N2)GO TO 345
      GO TO 348
 349  EFRY(N1+456,K)=EFRY(N1+456,K)+EFRY(N1+455,K)
      EFRY(N1+455,K)=0.
      N=N1
      GO TO 348
 354  N=N+1
      IF(N.EQ.N1+456)GO TO 280
      IF(N.EQ.N2)GO TO 356
      GO TO 353
 345  EFRY(N,K)=0.
 356  IF(I.EQ.N1+456)GO TO 344
      GO TO 282
 344  DO 346 M=N1,N1+455
      IF(M.EQ.N2)GO TO 282
      IF(M.GT.N1)GO TO 347
      FD(M,K)=FD(N1+455,K)-EFRY(M,K)+FRY(M,K)
      IF(FD(M,K).LT.0.)FD(M,K)=0.
      IF(FD(M,K).EQ.0.)GO TO 282
      FKIL(M,K)=FD(M,K)*FM(M,J)
C     WRITE(*,*)FKIL(I,K), J, K                    !DEBUG
      FD(M,K)=FD(M,K)-FKIL(M,K)
      GO TO 355
 347  FD(M,K)=FD(M-1,K)-EFRY(M,K)+FRY(M,K)
      IF(FD(M,K).LT.0.)FD(M,K)=0.
      IF(FD(M,K).EQ.0.)GO TO 282
      FKIL(M,K)=FD(M,K)*FM(M,J)
      FD(M,K)=FD(M,K)-FKIL(M,K)
 355  N=M+1
      IF(N.EQ.N2)GO TO 282
 373  IF(EFRY(N,K).EQ.0.)GO TO 374
      EFRY(N,K)=EFRY(N,K)-FKIL(M,K)
```

```
 358  IF(EFRY(N,K).GE.0.)GO TO 346
      EFRY(N+1,K)=EFRY(N+1,K)+EFRY(N,K)
      EFRY(N,K)=0.
      N=N+1
      IF(N.EQ.N2)GO TO 343
      GO TO 358
 374  N=N+1
      IF(N.EQ.N2)GO TO 346
      GO TO 373
 343  EFRY(N,K)=0.
 346  CONTINUE
 282  CONTINUE
 280  CONTINUE
C     DO 674 K=1,4
C     DO 675 II=1,911                          !debug
C        write(*,*)II , ESD(II,K), FRY(II,K), K !debug
C 675  CONTINUE
C 674  CONTINUE                                      !debug
C     DO 918 K=1,2
C     DO 919 II=1,456                     !DEBUC
C     WRITE(*,*)II,ED(II,K),EKIL(II,K),J,K                   !DEBUC
C 919  CONTINUE
C 918  CONTINUE                                 !DEBUC
C
C        DAILY FISH LOSS
C
      DO 600 K=K1,K2
      DO 601 I=N1,N1+455
      TAKIL(I,K)=TAKIL(I,K)+AKIL(I,K)
      TEKIL(I,K)=TEKIL(I,K)+EKIL(I,K)
      TFKIL(I,K)=TFKIL(I,K)+FKIL(I,K)
      TEFRY(I,K)=TEFRY(I,K)+EFRY(I,K)
 601  CONTINUE
 600  CONTINUE
 901  FORMAT(/7X,'JD',9X,'SPAWN',2X,'HATCH',2X,'EMERG',
     +9X,'AD',5X,'ED',5X,'FD',9X,'TEMP',3X,'PSM',5X,'EM',
     +5X,'FM',8X,'PSKIL',3X,'EKIL',3X,'FKIL'/)
 903  FORMAT(6X,I3,7X,3F7.2,5X,3F7.2,5X,4F7.2,5X,3F7.2)
 904  FORMAT(1H1,/10X,'REACH =',I2,10X,'SALMON RUN = ',A10/)
      IF(NY.NE.99)GO TO 900
      IF(J.NE.12)GO TO 900
      DO 905 K=1,1
      PRINT 904,J,NAME(K)
      PRINT 901
```

```
      WRITE(2, 904)J,NAME(K)
      WRITE(2, 901)
      DO 902 I=1,456
      FAD=AD(I,K)*100.
      FESD=ESD(I,K)*100.
      FFRY=FRY(I,K)*100.
      FED=ED(I,K)*100.
      FEFRY=EFRY(I,K)*100.
      FFD=FD(I,K)*100.
      FAKIL=AKIL(I,K)*100.
      FEKIL=EKIL(I,K)*100.
      FFKIL=FKIL(I,K)*100.
      FPSM=PSM(I,J)*100.
      FEM=EM(I,J)*100.
      FFM=FM(I,J)*100.
      PRINT 903,I,FESD,FFRY,FEFRY,FAD,FED,FFD,TR(I,J),FPSM,FEM,FFM,
     +FAKIL,FEKIL,FFKIL
      WRITE(2,903)I,FESD,FFRY,FEFRY,FAD,FED,FFD,TR(I,J),FPSM,FEM,FFM,
     +FAKIL,FEKIL,FFKIL
 902  CONTINUE
 905  CONTINUE
 900  CONTINUE
      DO 605 K=K1,K2
      DO 606 I=N1,N1+455
      TAKIL(I,K)=TAKIL(I,K)*100.
      TEKIL(I,K)=TEKIL(I,K)*100.
      TFKIL(I,K)=TFKIL(I,K)*100.
      TEFRY(I,K)=TEFRY(I,K)*100.
 606  CONTINUE
 605  CONTINUE
C
C          ANNUAL FISH LOSS
C
      DO 610 K=K1,K2
      CAK(K)=0.
      CEK(K)=0.
      CFK(K)=0.
      DO 611 I=N1,N1+455
      CAK(K)=CAK(K)+TAKIL(I,K)
      CEK(K)=CEK(K)+TEKIL(I,K)
      CFK(K)=CFK(K)+TFKIL(I,K)
      CEFRY(K)=CEFRY(K)+TEFRY(I,K)
 611  CONTINUE
      IF(CAK(K).GT.100.)CAK(K)=100.
```

```
      IF(CEK(K).GT.100.)CEK(K)=100.
      IF(CFK(K).GT.100.)CFK(K)=100.
      IF(CEFRY(K).GT.100.)CEFRY(K)=100.
 610  CONTINUE
C
C        TOTAL FISH LOSS
C
      DO 630 K=K1,K2
      TOTKIL(K)=CAK(K)+CEK(K)+CFK(K)
      IF(TOTKIL(K).GT.100.)TOTKIL(K)=100.
      ATK(K)=ATK(K)+TOTKIL(K)
 630  CONTINUE
      TOTRKIL=TOTKIL(K1)+TOTKIL(K2)
      TOTEFRY(1)=CEFRY(1)+CEFRY(2)
      TOTEFRY(2)=CEFRY(3)+CEFRY(4)
      IF(TOTRKIL.GT.100.)TOTRKIL=100.
      ATRK=ATRK+TOTRKIL
C
C            MONTHLY VALUES
C
      DO 700 M=1,30
      II=JULB(M)
      NN=JULE(M)
      DAYS=NN-II+1
      DO 703 K=K1,K2
      ATAKIL(M,K)=0.
      ATEKIL(M,K)=0.
      ATFKIL(M,K)=0.
      DO 704 I=II,NN
      ATAKIL(M,K)=ATAKIL(M,K)+TAKIL(I,K)
      ATEKIL(M,K)=ATEKIL(M,K)+TEKIL(I,K)
      ATFKIL(M,K)=ATFKIL(M,K)+TFKIL(I,K)
 704  CONTINUE
      TOTMKIL(M,K)=ATAKIL(M,K)+ATEKIL(M,K)+ATFKIL(M,K)
 703  CONTINUE
 700  CONTINUE
      GO TO 440
C
C            PRINT RESULTS
C
 800  FORMAT(1H1,/34X,'SACRAMENTO RIVER MEAN MONTHLY FLOWS - CFS')
 801  FORMAT(/6X,'MONTH',5X,'SHASTA',4X,'SPRING CR',5X,
     +'KESWICK',4X,'CLEAR CR',5X,'COW CR',4X,'COTTNWD CR',4X,
     +'BEND BR',4X,'RED BLUFF')
```

```
 802  FORMAT(16X,'0.0 MI',5X,'8.0 MI',7X,'9.0 MI',6X,'21.8 MI',
     +5X,'31.0 MI',5X,'37.5 MI',5X,'53.6 MI',5X,'65.9 MI'/)
 803  FORMAT(/6X,I3,1X,8F12.0)
 804  FORMAT(///30X,'SACRAMENTO RIVER MEAN MONTHLY TEMPERATURES - F')
 805  FORMAT(/6X,I3,8F12.1)
 806  FORMAT(1H1,//45X,'SACRAMENTO RIVER SALMON MORTALITIES - % OF
RUN')
 807  FORMAT(/26X,'FALL RUN',20X,'LATE-FALL RUN',18X,
     +'WINTER RUN',19X,'SPRING RUN')
 808  FORMAT(/6X,'MONTH',8X,'PSPAWN',4X,'EGG',5X,'FRY',9X,
     +'PSPAWN',4X,'EGG',5X,'FRY',9X,'PSPAWN',4X,'EGG',5X,'FRY',9X,
     +'PSPAWN',4X,'EGG',5X,'FRY')
 908  FORMAT(/8X,'DAY',8X,'PSPAWN',4X,'EGG',5X,'FRY',9X,
     +'PSPAWN',4X,'EGG',5X,'FRY',9X,'PSPAWN',4X,'EGG',5X,'FRY',9X,
     +'PSPAWN',4X,'EGG',5X,'FRY')
 809  FORMAT(/6X,I3,8X,3F8.3,6X,3F8.3,6X,3F8.3,6X,3F8.3)
 909  FORMAT(6X,I3,8X,3F8.3,6X,3F8.3,6X,3F8.3,6X,3F8.3)
 810  FORMAT(/26X,'FEATHER RIVER SALMON LOSS SUMMARY - %')
 811  FORMAT(/16X,'YEAR',11X,' LFC  ',6X,' HFC  ',6X,'TOTAL',12X,
     +'EMERGENT FRY PRODUCTION'/)
 812  FORMAT(//16X,'PSPAWN - %',5X,4F12.1)
 813  FORMAT(/16X,'EGG - %',8X,4F12.1)
 814  FORMAT(/16X,'FRY - %',8X,4F12.1)
 815  FORMAT(/16X,'EFRY - %',6X,4F12.1)
 816  FORMAT(//16X,'TOTAL RUN - %',2X,4F12.1)
 817  FORMAT(//16X,'FISH LOSS',6X,5F12.1)
 441  FORMAT(16X,I4,3X,3F12.1,12X,F12.1)
 442  FORMAT(//15X,'FEATHER RIVER SALMON MODEL - CALSIM VERSION')
 443  FORMAT(/14X,'AVERAGE',2X,3F12.1)
 444  FORMAT(//26X,'MONTHLY LOSS SUMMARY - %')
 544  FORMAT(//26X,'LIFE STAGE LOSS SUMMARY - %')
 545  FORMAT(/12X,'YEAR',3X,'REACH',4X,'ADULTS',5X,'EGGS',5X,
     +'PRE-EMERGENT FRY'/)
 546  FORMAT(12X,I4,3X,'LFC ',3F10.1)
 547  FORMAT(12X,I4,3X,'HFC ',3F10.1)
 446  FORMAT(/14X,12A10)
 449  FORMAT(4X,'LFC')
 453  FORMAT(/4X,'HFC')
 448  FORMAT(3X,'Adults  ',12F10.3)
 450  FORMAT(3X,'Eggs    ',12F10.3)
 451  FORMAT(3X,'P.E. fry',12F10.3)
 452  FORMAT(3X,'Totals  ',12F10.3)
 447  FORMAT(/15X,2A10)
      DO 830 M=1,12
```

```
      IF(M.GT.N1)GO TO 831
      PRINT 804
      PRINT 801
      PRINT 802
      WRITE(2,804)
      WRITE(2,801)
      WRITE(2,802)
831  PRINT 805,M,(AT(M,J),J=1,8)
      WRITE(2,805)M,(AT(M,J),J=1,8)
830  CONTINUE
      DO 940 I=N1,N1+455
      IF(I.GT.N1)GO TO 941
      PRINT 806
      PRINT 807
      PRINT 908
      WRITE(2,806)
      WRITE(2,807)
      WRITE(2,908)
941  PRINT 909,I,TAKIL(I,1),TEKIL(I,1),TFKIL(I,1),
     +TAKIL(I,2),TEKIL(I,2),TFKIL(I,2),TAKIL(I,3),
     +TEKIL(I,3),TFKIL(I,3),TAKIL(I,4),TEKIL(I,4),
     +TFKIL(I,4)
      WRITE(2,909)I,TAKIL(I,1),TEKIL(I,1),TFKIL(I,1),
     +TAKIL(I,2),TEKIL(I,2),TFKIL(I,2),TAKIL(I,3),
     +TEKIL(I,3),TFKIL(I,3),TAKIL(I,4),TEKIL(I,4),
     +TFKIL(I,4)
940  CONTINUE
      DO 840 M=1,12
      IF(M.GT.N1)GO TO 841
      PRINT 806
      PRINT 807
      PRINT 808
      WRITE(2,806)
      WRITE(2,807)
      WRITE(2,808)
841  PRINT 809,M,ATAKIL(M,1),ATEKIL(M,1),ATFKIL(M,1),
     +ATAKIL(M,2),ATEKIL(M,2),ATFKIL(M,2),ATAKIL(M,3),
     +ATEKIL(M,3),ATFKIL(M,3),ATAKIL(M,4),ATEKIL(M,4),
     +ATFKIL(M,4)
      WRITE(2,809)M,ATAKIL(M,1),ATEKIL(M,1),ATFKIL(M,1),
     +ATAKIL(M,2),ATEKIL(M,2),ATFKIL(M,2),ATAKIL(M,3),
     +ATEKIL(M,3),ATFKIL(M,3),ATAKIL(M,4),ATEKIL(M,4),
     +ATFKIL(M,4)
840  CONTINUE
```

```
      PRINT 810
      PRINT 811
      PRINT 812,(CAK(K),K=K1,K2)
      PRINT 813,(CEK(K),K=K1,K2)
      PRINT 814,(CFK(K),K=K1,K2)
      PRINT 816,(TOTKIL(K),K=K1,K2)
 440  IF(NY.NE.1)GO TO 445
      WRITE(2,442)
      WRITE(2,810)
      WRITE(2,811)
 445  WRITE(2,441)IYR(NY),(TOTKIL(K),K=K1,K2),TOTRKIL,
     +TOTEFRY(NY)
 400  CONTINUE
C     DO 450 K=1,2
      ATK(1)=(ATK(1)+ATK(3))/NYR                    !NEED TO CHANGE THIS IF THERE
ARE MORE THAN TWO YEARS OF DATA!!!
      ATK(2)=(ATK(2)+ATK(4))/NYR
C 450  CONTINUE
      ATRK=ATRK/NYR
      WRITE(2,443)(ATK(K),K=1,2),ATRK
      WRITE(2,544)
      WRITE(2,545)
      WRITE(2,546)IYR(1),CAK(1),CEK(1),CFK(1)
      WRITE(2,547)IYR(1),CAK(2),CEK(2),CFK(2)
      WRITE(2,546)IYR(2),CAK(3),CEK(3),CFK(3)
      WRITE(2,547)IYR(2),CAK(4),CEK(4),CFK(4)
      WRITE(2,444)
      WRITE(2,446)(MONTH(Q),Q=1,12)
      WRITE(2,449)
      WRITE(2,448)(ATAKIL(M,1),M=1,12)
      WRITE(2,450)(ATEKIL(M,1),M=1,12)
      WRITE(2,451)(ATFKIL(M,1),M=1,12)
      WRITE(2,452)(TOTMKIL(M,1),M=1,12)
      WRITE(2,453)
      WRITE(2,448)(ATAKIL(M,2),M=1,12)
      WRITE(2,450)(ATEKIL(M,2),M=1,12)
      WRITE(2,451)(ATFKIL(M,2),M=1,12)
      WRITE(2,452)(TOTMKIL(M,2),M=1,12)
      WRITE(2,446)(MONTH(Q),Q=13,24)
      WRITE(2,449)
      WRITE(2,448)(ATAKIL(M,3),M=13,24)
      WRITE(2,450)(ATEKIL(M,3),M=13,24)
      WRITE(2,451)(ATFKIL(M,3),M=13,24)
      WRITE(2,452)(TOTMKIL(M,3),M=13,24)
```

```
WRITE(2,453)
WRITE(2,448)(ATAKIL(M,4),M=13,24)
WRITE(2,450)(ATEKIL(M,4),M=13,24)
WRITE(2,451)(ATFKIL(M,4),M=13,24)
WRITE(2,452)(TOTMKIL(M,4),M=13,24)
WRITE(2,446)(MONTH(Q),Q=25,30)
WRITE(2,449)
WRITE(2,448)(ATAKIL(M,3),M=25,30)
WRITE(2,450)(ATEKIL(M,3),M=25,30)
WRITE(2,451)(ATFKIL(M,3),M=25,30)
WRITE(2,452)(TOTMKIL(M,3),M=25,30)
WRITE(2,453)
WRITE(2,448)(ATAKIL(M,4),M=25,30)
WRITE(2,450)(ATEKIL(M,4),M=25,30)
WRITE(2,451)(ATFKIL(M,4),M=25,30)
WRITE(2,452)(TOTMKIL(M,4),M=25,30)
END
```

State of California
The Resources Agency
Department of Water Resources

FINAL REPORT
EVALUATION OF THE TIMING, MAGNITUDE AND FREQUENCY OF WATER TEMPERATURES AND THEIR EFFECTS ON CHINOOK SALMON EGG AND ALEVIN SURVIVAL
SP-F10, TASK 2C

OROVILLE FACILITIES RELICENSING
FERC PROJECT NO. 2100

APPENDIX B
AVERAGE DAILY WATER TEMPERATURE PER MODEL REACH FROM FEBRUARY 2, 2002 TO FEBRUARY 10, 2004

JUNE 2004

Table B-1. Average mean daily water temperature per model reach in February 2, 2002 - March 17, 2002.

Date	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
2/5/02	47.117	47.106	47.094	47.080	47.063	47.047	47.033	46.991	46.900
2/6/02	46.959	47.023	47.056	47.071	47.076	47.077	47.078	47.078	47.078
2/7/02	47.268	47.775	48.081	48.237	48.296	48.309	48.310	48.310	48.310
2/8/02	47.321	48.037	48.522	48.816	48.956	48.997	49.006	49.007	49.007
2/9/02	47.771	48.150	48.377	48.493	48.538	48.548	48.550	48.550	48.550
2/10/02	47.976	48.443	48.731	48.885	48.947	48.962	48.964	48.964	48.964
2/11/02	48.698	49.174	49.465	49.618	49.679	49.693	49.695	49.695	49.695
2/12/02	48.772	49.521	50.018	50.309	50.441	50.476	50.483	50.484	50.484
2/13/02	48.619	49.469	50.045	50.393	50.557	50.603	50.612	50.613	50.613
2/14/02	48.509	49.627	50.418	50.922	51.173	51.249	51.265	51.268	51.268
2/15/02	48.555	49.846	50.776	51.380	51.687	51.782	51.802	51.805	51.805
2/16/02	48.538	49.766	50.643	51.207	51.491	51.577	51.595	51.598	51.598
2/17/02	48.538	49.766	50.643	51.207	51.491	51.577	51.595	51.598	51.598
2/18/02	48.497	49.564	50.299	50.749	50.961	51.020	51.031	51.033	51.033
2/19/02	47.999	49.228	50.102	50.661	50.939	51.022	51.039	51.041	51.042
2/20/02	48.226	49.633	50.649	51.308	51.640	51.740	51.760	51.764	51.764
2/21/02	48.831	50.491	51.714	52.528	52.948	53.077	53.104	53.109	53.109
2/22/02	48.982	50.523	51.647	52.383	52.757	52.871	52.894	52.898	52.898
2/23/02	48.697	50.544	51.944	52.912	53.435	53.608	53.647	53.654	53.654
2/24/02	49.389	51.119	52.411	53.288	53.751	53.900	53.933	53.939	53.939
2/25/02	51.576	52.694	53.434	53.857	54.038	54.081	54.087	54.088	54.088
2/26/02	51.915	52.955	53.632	54.012	54.171	54.207	54.213	54.213	54.213
2/27/02	51.960	53.172	53.989	54.469	54.680	54.733	54.742	54.743	54.743
2/28/02	51.651	53.062	54.044	54.648	54.928	55.004	55.017	55.019	55.019
3/1/02	50.018	51.366	52.275	52.805	53.032	53.086	53.093	53.094	53.094
3/2/02	49.738	50.698	51.287	51.587	51.695	51.715	51.717	51.718	51.718
3/3/02	49.811	51.024	51.766	52.135	52.261	52.282	52.283	52.284	52.284
3/4/02	50.046	51.462	52.345	52.795	52.952	52.978	52.980	52.980	52.980
3/5/02	49.721	51.282	52.303	52.861	53.075	53.117	53.121	53.121	53.121
3/6/02	49.394	51.094	52.255	52.933	53.219	53.282	53.290	53.291	53.291
3/7/02	49.088	51.005	52.357	53.180	53.546	53.634	53.646	53.648	53.648
3/8/02	48.800	50.308	51.337	51.943	52.205	52.266	52.275	52.276	52.276
3/9/02	48.361	49.564	50.349	50.786	50.963	51.000	51.005	51.006	51.006
3/10/02	48.370	49.611	50.433	50.899	51.091	51.134	51.140	51.141	51.141
3/11/02	48.985	50.512	51.568	52.203	52.484	52.553	52.564	52.565	52.565
3/12/02	49.346	50.879	51.941	52.579	52.864	52.934	52.945	52.946	52.946
3/13/02	49.001	50.597	51.717	52.405	52.719	52.800	52.812	52.814	52.814
3/14/02	49.153	50.645	51.685	52.321	52.612	52.687	52.699	52.701	52.701
3/15/02	48.788	50.262	51.294	51.928	52.220	52.297	52.309	52.311	52.311
3/16/02	48.788	50.262	51.294	51.928	52.220	52.297	52.309	52.311	52.311
3/17/02	48.576	49.922	50.843	51.390	51.632	51.692	51.701	51.702	51.702

Table B-2. Average mean daily water temperature per model reach in March 18, 2002 - April 27, 2002.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
3/18/02	48.666	49.667	50.307	50.654	50.791	50.820	50.824	50.824	50.824
3/19/02	48.885	50.028	50.770	51.180	51.345	51.381	51.385	51.386	51.386
3/20/02	49.217	50.932	52.109	52.802	53.096	53.163	53.172	53.172	53.172
3/21/02	49.500	51.610	53.105	54.017	54.419	54.513	54.525	54.526	54.526
3/22/02	49.006	51.310	52.991	54.060	54.557	54.682	54.701	54.702	54.702
3/23/02	48.783	50.906	52.423	53.360	53.779	53.879	53.893	53.895	53.895
3/24/02	49.166	51.384	52.986	53.990	54.448	54.561	54.577	54.579	54.579
3/25/02	50.554	52.561	53.962	54.800	55.161	55.243	55.254	55.255	55.255
3/26/02	49.909	52.594	54.636	56.013	56.704	56.899	56.932	56.936	56.936
3/27/02	49.319	51.663	53.737	55.555	56.935	57.696	58.022	58.197	58.217
3/28/02	49.445	52.082	54.363	56.277	57.624	58.280	58.516	58.608	58.616
3/29/02	49.598	52.433	54.929	57.073	58.631	59.421	59.720	59.845	59.856
3/30/02	49.375	52.329	54.984	57.339	59.128	60.096	60.493	60.683	60.702
3/31/02	50.947	53.196	55.285	57.272	58.975	60.108	60.725	61.249	61.356
4/1/02	53.377	55.122	56.746	58.312	59.698	60.676	61.256	61.866	62.038
4/2/02	52.831	55.526	57.885	59.909	61.390	62.158	62.460	62.598	62.611
4/3/02	51.225	54.447	57.287	59.715	61.451	62.302	62.607	62.721	62.730
4/4/02	50.262	52.796	55.130	57.306	59.106	60.231	60.794	61.193	61.256
4/5/02	50.402	52.542	54.504	56.337	57.870	58.855	59.371	59.779	59.854
4/6/02	51.567	53.731	55.666	57.402	58.775	59.587	59.971	60.219	60.255
4/7/02	53.514	55.414	57.114	58.650	59.889	60.650	61.031	61.311	61.360
4/8/02	55.746	57.155	58.435	59.631	60.655	61.351	61.749	62.146	62.252
4/9/02	55.136	56.703	58.034	59.156	59.983	60.433	60.629	60.744	60.759
4/10/02	54.935	56.838	58.349	59.484	60.182	60.468	60.554	60.579	60.581
4/11/02	54.057	56.718	58.928	60.672	61.800	62.283	62.431	62.475	62.478
4/12/02	54.089	56.927	59.330	61.277	62.580	63.164	63.355	63.417	63.421
4/13/02	53.865	57.092	59.853	62.105	63.610	64.275	64.484	64.547	64.551
4/14/02	53.625	56.989	59.975	62.559	64.442	65.392	65.745	65.887	65.898
4/15/02	53.179	55.935	58.376	60.507	62.105	62.964	63.317	63.491	63.508
4/16/02	52.702	54.445	56.034	57.519	58.776	59.609	60.066	60.475	60.566
4/17/02	52.736	54.020	55.163	56.201	57.055	57.606	57.901	58.162	58.220
4/18/02	52.717	54.500	55.969	57.139	57.925	58.295	58.427	58.481	58.486
4/19/02	52.437	54.679	56.529	57.986	58.935	59.351	59.484	59.529	59.532
4/20/02	52.067	54.544	56.678	58.471	59.748	60.386	60.626	60.728	60.738
4/21/02	51.899	54.421	56.662	58.638	60.148	60.987	61.350	61.546	61.568
4/22/02	52.289	54.903	57.250	59.350	60.987	61.923	62.342	62.581	62.610
4/23/02	52.011	55.102	57.872	60.317	62.162	63.149	63.549	63.735	63.753
4/24/02	51.556	54.743	57.616	60.172	62.115	63.165	63.594	63.795	63.815
4/25/02	51.652	55.045	58.049	60.628	62.479	63.386	63.710	63.830	63.839
4/26/02	51.178	53.956	56.471	58.739	60.520	61.543	62.001	62.260	62.292
4/27/02	50.571	52.871	54.939	56.803	58.281	59.154	59.563	59.823	59.859

Table B-3. Average mean daily water temperature per model reach in April 28, 2002 - June 7, 2002.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
4/28/02	50.735	52.861	54.767	56.483	57.847	58.661	59.049	59.306	59.345
4/29/02	50.633	52.523	54.257	55.884	57.264	58.175	58.671	59.101	59.192
4/30/02	50.966	52.630	54.137	55.532	56.697	57.455	57.863	58.212	58.287
5/1/02	51.565	53.820	55.771	57.430	58.640	59.271	59.524	59.646	59.659
5/2/02	52.034	54.548	56.525	58.143	59.403	60.225	60.711	61.349	61.718
5/3/02	51.752	54.382	56.421	58.061	59.313	60.114	60.578	61.168	61.491
5/4/02	51.824	54.558	56.737	58.549	59.984	60.939	61.513	62.293	62.765
5/5/02	52.568	55.160	57.312	59.190	60.757	61.863	62.565	63.615	64.352
5/6/02	52.864	55.550	57.782	59.732	61.359	62.508	63.238	64.332	65.102
5/7/02	52.187	55.267	57.723	59.766	61.384	62.461	63.110	63.990	64.523
5/8/02	52.092	55.138	57.495	59.389	60.834	61.756	62.290	62.967	63.336
5/9/02	52.024	55.051	57.413	59.329	60.805	61.758	62.315	63.035	63.439
5/10/02	52.223	55.076	57.310	59.131	60.540	61.455	61.994	62.694	63.093
5/11/02	52.728	55.605	57.832	59.622	60.986	61.858	62.362	63.002	63.351
5/12/02	53.745	56.747	59.046	60.868	62.239	63.099	63.590	64.196	64.515
5/13/02	54.476	57.295	59.509	61.318	62.724	63.640	64.181	64.890	65.296
5/14/02	52.900	56.794	59.647	61.794	63.319	64.219	64.702	65.243	65.489
5/15/02	52.681	56.363	59.231	61.551	63.334	64.481	65.150	66.010	66.489
5/16/02	52.827	56.351	59.179	61.549	63.442	64.714	65.486	66.550	67.209
5/17/02	53.099	56.416	59.129	61.454	63.355	64.668	65.485	66.662	67.443
5/18/02	53.224	55.791	57.963	59.901	61.556	62.756	63.536	64.758	65.679
5/19/02	52.751	55.171	57.086	58.664	59.902	60.717	61.203	61.850	62.231
5/20/02	52.861	55.043	56.611	57.766	58.568	59.029	59.270	59.529	59.640
5/21/02	52.458	55.148	56.850	57.930	58.568	58.873	59.008	59.118	59.151
5/22/02	52.610	55.574	57.620	59.058	60.006	60.519	60.774	61.025	61.120
5/23/02	53.132	56.249	58.508	60.187	61.364	62.048	62.410	62.806	62.980
5/24/02	53.167	56.708	59.327	61.320	62.753	63.610	64.076	64.609	64.859
5/25/02	53.468	56.909	59.591	61.766	63.439	64.519	65.150	65.963	66.418
5/26/02	54.449	57.393	59.784	61.817	63.465	64.592	65.287	66.272	66.909
5/27/02	55.096	57.672	59.810	61.675	63.230	64.327	65.023	66.062	66.791
5/28/02	55.106	58.444	61.018	63.078	64.641	65.634	66.206	66.924	67.312
5/29/02	54.687	59.157	62.435	64.907	66.666	67.704	68.264	68.891	69.177
5/30/02	54.928	59.657	63.255	66.088	68.201	69.518	70.262	71.169	71.636
5/31/02	54.678	59.590	63.394	66.452	68.784	70.274	71.136	72.230	72.828
6/1/02	54.396	58.763	62.182	64.964	67.117	68.513	69.334	70.400	71.005
6/2/02	54.836	59.565	62.958	65.449	67.174	68.161	68.677	69.228	69.463
6/3/02	55.516	60.399	63.882	66.424	68.170	69.162	69.676	70.219	70.446
6/4/02	54.920	60.411	64.349	67.239	69.238	70.381	70.979	71.616	71.887
6/5/02	54.722	60.266	64.387	67.545	69.832	71.209	71.964	72.837	73.254
6/6/02	54.620	59.367	63.134	66.250	68.702	70.324	71.294	72.597	73.371
6/7/02	54.653	58.781	62.153	65.038	67.395	69.018	70.027	71.477	72.434

Table B-4. Average mean daily water temperature per model reach in June 8, 2002 - July 18, 2002.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
6/8/02	54.760	57.432	59.763	61.917	63.830	65.277	66.258	67.910	69.315
6/9/02	54.818	57.002	58.860	60.529	61.964	63.013	63.701	64.791	65.632
6/10/02	55.214	57.806	59.856	61.543	62.866	63.735	64.253	64.941	65.346
6/11/02	54.509	58.396	61.169	63.192	64.582	65.371	65.780	66.212	66.393
6/12/02	54.702	58.317	61.127	63.395	65.133	66.248	66.897	67.727	68.186
6/13/02	55.360	58.254	60.646	62.723	64.445	65.651	66.413	67.540	68.318
6/14/02	58.578	60.002	61.277	62.491	63.605	64.479	65.092	66.192	67.234
6/15/02	59.893	61.350	62.588	63.697	64.651	65.346	65.802	66.521	67.074
6/16/02	60.080	61.851	63.245	64.386	65.274	65.855	66.198	66.650	66.910
6/17/02	59.796	62.681	64.608	65.910	66.733	67.158	67.360	67.545	67.609
6/18/02	60.785	63.723	65.817	67.344	68.392	68.986	69.294	69.618	69.754
6/19/02	60.869	63.832	66.029	67.706	68.917	69.643	70.039	70.495	70.711
6/20/02	58.395	62.375	65.226	67.315	68.758	69.581	70.011	70.468	70.662
6/21/02	56.522	60.602	63.565	65.772	67.323	68.226	68.706	69.232	69.465
6/22/02	56.143	60.406	63.409	65.569	67.029	67.844	68.259	68.686	68.858
6/23/02	56.265	60.659	63.811	66.127	67.731	68.648	69.128	69.641	69.859
6/24/02	56.394	60.659	63.826	66.247	67.997	69.049	69.625	70.288	70.604
6/25/02	56.657	60.635	63.709	66.173	68.048	69.241	69.930	70.800	71.272
6/26/02	57.303	60.434	62.991	65.180	66.966	68.198	68.963	70.062	70.787
6/27/02	57.339	60.087	62.347	64.297	65.904	67.022	67.723	68.748	69.441
6/28/02	58.289	60.803	62.850	64.595	66.013	66.986	67.588	68.447	69.006
6/29/02	58.564	61.371	63.510	65.196	66.457	67.243	67.688	68.233	68.514
6/30/02	58.927	62.106	64.427	66.166	67.397	68.119	68.506	68.934	69.127
7/1/02	58.918	62.162	64.586	66.454	67.817	68.643	69.100	69.634	69.893
7/2/02	59.137	61.757	63.883	65.687	67.148	68.145	68.760	69.628	70.187
7/3/02	57.322	60.462	62.879	64.808	66.268	67.193	67.725	68.390	68.746
7/4/02	57.055	60.414	62.923	64.856	66.264	67.119	67.590	68.141	68.409
7/5/02	57.402	60.164	62.379	64.234	65.715	66.709	67.313	68.143	68.657
7/6/02	58.267	60.223	61.907	63.439	64.775	65.768	66.428	67.504	68.372
7/7/02	58.617	60.431	61.973	63.356	64.544	65.411	65.979	66.878	67.568
7/8/02	59.157	61.256	62.911	64.268	65.327	66.021	66.431	66.974	67.289
7/9/02	59.896	62.010	63.668	65.022	66.072	66.755	67.158	67.684	67.985
7/10/02	59.912	62.492	64.407	65.871	66.929	67.564	67.912	68.312	68.502
7/11/02	57.710	61.292	63.877	65.789	67.122	67.892	68.297	68.736	68.927
7/12/02	55.963	59.986	62.938	65.165	66.751	67.688	68.193	68.761	69.020
7/13/02	56.055	59.555	62.276	64.472	66.156	67.237	67.865	68.670	69.115
7/14/02	56.090	59.349	61.921	64.035	65.688	66.772	67.417	68.271	68.770
7/15/02	55.916	58.937	61.350	63.361	64.957	66.022	66.665	67.541	68.074
7/16/02	56.504	58.556	60.336	61.969	63.409	64.488	65.214	66.419	67.419
7/17/02	57.388	58.887	60.243	61.553	62.773	63.746	64.438	65.718	66.990
7/18/02	57.777	59.338	60.715	62.005	63.168	64.061	64.676	65.741	66.691

Table B-5. Average mean daily water temperature per model reach in July 19, 2002 - August 28, 2002.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
7/19/02	57.978	60.024	61.689	63.107	64.258	65.047	65.534	66.227	66.678
7/20/02	58.320	60.857	62.798	64.338	65.496	66.223	66.638	67.150	67.420
7/21/02	58.402	60.694	62.528	64.061	65.282	66.098	66.592	67.269	67.685
7/22/02	57.993	61.023	63.191	64.778	65.873	66.497	66.821	67.166	67.312
7/23/02	57.519	60.701	63.036	64.798	66.054	66.797	67.197	67.647	67.853
7/24/02	57.471	60.379	62.612	64.389	65.730	66.576	67.060	67.662	67.982
7/25/02	57.858	60.140	62.007	63.610	64.922	65.829	66.395	67.212	67.755
7/26/02	58.591	60.381	61.912	63.295	64.493	65.374	65.956	66.889	67.624
7/27/02	59.471	61.196	62.645	63.926	65.011	65.789	66.290	67.061	67.626
7/28/02	59.802	62.041	63.748	65.094	66.100	66.728	67.085	67.520	67.746
7/29/02	59.483	62.147	64.089	65.543	66.570	67.171	67.492	67.848	68.008
7/30/02	57.386	60.838	63.385	65.318	66.705	67.531	67.979	68.489	68.726
7/31/02	57.393	60.689	63.184	65.137	66.585	67.480	67.983	68.589	68.896
8/1/02	57.769	60.317	62.405	64.198	65.669	66.688	67.323	68.243	68.858
8/2/02	58.535	60.549	62.265	63.809	65.142	66.117	66.759	67.780	68.574
8/3/02	59.237	60.830	62.219	63.503	64.643	65.506	66.091	67.076	67.914
8/4/02	59.723	61.299	62.598	63.721	64.649	65.297	65.705	66.303	66.712
8/5/02	60.294	62.075	63.466	64.597	65.469	66.034	66.364	66.793	67.034
8/6/02	60.200	61.951	63.339	64.486	65.388	65.984	66.340	66.817	67.100
8/7/02	58.081	61.267	63.456	64.984	65.986	66.524	66.790	67.049	67.146
8/8/02	57.900	60.715	62.819	64.440	65.623	66.340	66.737	67.200	67.425
8/9/02	58.728	61.050	62.899	64.437	65.653	66.461	66.947	67.606	68.003
8/10/02	59.527	61.423	63.001	64.382	65.537	66.354	66.874	67.657	68.211
8/11/02	59.349	61.661	63.461	64.919	66.038	66.760	67.180	67.721	68.023
8/12/02	59.534	61.895	63.738	65.231	66.382	67.124	67.558	68.118	68.432
8/13/02	61.206	62.975	64.434	65.697	66.740	67.469	67.927	68.601	69.061
8/14/02	61.080	63.157	64.798	66.147	67.203	67.895	68.307	68.853	69.173
8/15/02	58.507	61.785	64.203	66.040	67.357	68.142	68.568	69.053	69.279
8/16/02	58.182	61.531	64.010	65.900	67.261	68.075	68.520	69.028	69.268
8/17/02	58.396	61.510	63.849	65.664	66.996	67.811	68.264	68.800	69.065
8/18/02	57.984	61.177	63.575	65.433	66.796	67.629	68.092	68.640	68.910
8/19/02	57.784	60.654	62.868	64.639	65.983	66.837	67.329	67.947	68.280
8/20/02	58.844	60.721	62.287	63.660	64.813	65.631	66.154	66.945	67.510
8/21/02	59.596	60.982	62.201	63.339	64.360	65.142	65.677	66.597	67.407
8/22/02	61.102	61.797	62.459	63.137	63.811	64.388	64.826	65.750	66.900
8/23/02	58.406	61.013	62.806	64.058	64.879	65.321	65.539	65.752	65.832
8/24/02	58.545	60.937	62.699	64.034	64.989	65.557	65.865	66.214	66.375
8/25/02	57.610	60.825	63.075	64.680	65.757	66.351	66.652	66.956	67.076
8/26/02	57.001	59.630	61.785	63.639	65.160	66.215	66.874	67.830	68.470
8/27/02	59.101	60.518	61.818	63.094	64.304	65.287	65.999	67.364	68.803
8/28/02	60.043	61.820	63.337	64.704	65.884	66.749	67.319	68.228	68.938

Table B-6. Average mean daily water temperature per model reach in August 29, 2002 - October 8, 2002.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
8/29/02	58.263	61.098	63.301	65.081	66.445	67.321	67.831	68.484	68.845
8/30/02	54.802	59.258	62.474	64.855	66.516	67.476	67.981	68.529	68.767
8/31/02	54.198	58.317	61.493	64.032	65.959	67.181	67.884	68.768	69.243
9/1/02	54.359	58.361	61.490	64.035	66.002	67.276	68.023	68.993	69.542
9/2/02	54.249	58.005	61.040	63.605	65.671	67.074	67.933	69.136	69.900
9/3/02	55.417	57.769	59.862	61.844	63.652	65.060	66.040	67.779	69.390
9/4/02	54.682	56.823	58.738	60.564	62.238	63.553	64.474	66.128	67.694
9/5/02	54.071	56.600	58.704	60.542	62.077	63.162	63.852	64.887	65.617
9/6/02	54.605	56.874	58.761	60.411	61.790	62.765	63.386	64.318	64.976
9/7/02	54.794	57.266	59.236	60.875	62.173	63.036	63.556	64.262	64.688
9/8/02	54.833	57.704	59.881	61.588	62.857	63.643	64.086	64.622	64.895
9/9/02	54.913	57.776	59.993	61.776	63.137	64.007	64.510	65.150	65.500
9/10/02	53.391	57.142	59.934	62.076	63.630	64.567	65.082	65.680	65.966
9/11/02	51.788	56.069	59.275	61.753	63.564	64.667	65.278	65.996	66.347
9/12/02	51.555	55.461	58.532	61.046	63.002	64.279	65.034	66.026	66.598
9/13/02	52.275	55.483	58.119	60.392	62.264	63.565	64.380	65.569	66.372
9/14/02	52.516	55.397	57.808	59.931	61.720	62.996	63.815	65.062	65.964
9/15/02	52.272	54.816	57.011	59.016	60.774	62.084	62.960	64.398	65.572
9/16/02	52.209	54.814	57.012	58.965	60.626	61.824	62.601	63.807	64.705
9/17/02	54.437	56.392	58.089	59.651	61.031	62.069	62.768	63.934	64.909
9/18/02	54.429	57.068	59.164	60.899	62.267	63.172	63.714	64.443	64.878
9/19/02	52.523	55.920	58.552	60.669	62.287	63.320	63.920	64.681	65.099
9/20/02	51.238	54.904	57.796	60.170	62.023	63.238	63.958	64.911	65.465
9/21/02	51.301	54.860	57.697	60.056	61.923	63.166	63.913	64.928	65.540
9/22/02	51.555	55.282	58.193	60.556	62.379	63.557	64.247	65.140	65.642
9/23/02	51.391	55.285	58.319	60.776	62.666	63.884	64.596	65.511	66.023
9/24/02	52.868	55.674	58.036	60.132	61.911	63.191	64.020	65.300	66.249
9/25/02	53.249	55.792	57.958	59.907	61.586	62.814	63.621	64.905	65.899
9/26/02	53.496	55.437	57.191	58.880	60.448	61.695	62.580	64.206	65.808
9/27/02	54.107	55.344	56.516	57.713	58.896	59.905	60.667	62.259	64.208
9/28/02	53.953	55.410	56.724	57.988	59.159	60.088	60.746	61.952	63.133
9/29/02	53.374	55.582	57.381	58.917	60.168	61.028	61.561	62.322	62.822
9/30/02	52.769	55.219	57.196	58.866	60.209	61.120	61.678	62.457	62.951
10/1/02	52.944	54.671	56.166	57.535	58.740	59.642	60.248	61.249	62.075
10/2/02	54.234	55.000	55.722	56.453	57.169	57.773	58.225	59.153	60.253
10/3/02	53.641	54.925	56.004	56.962	57.773	58.357	58.734	59.316	59.745
10/4/02	53.041	55.050	56.605	57.853	58.805	59.412	59.764	60.209	60.451
10/5/02	53.607	55.505	57.049	58.362	59.429	60.159	60.610	61.251	61.668
10/6/02	54.440	56.182	57.647	58.946	60.048	60.840	61.352	62.142	62.725
10/7/02	55.446	56.941	58.245	59.450	60.518	61.326	61.874	62.794	63.577
10/8/02	55.542	57.166	58.570	59.854	60.981	61.823	62.386	63.314	64.076

Table B-7. Average mean daily water temperature per model reach in October 9, 2002 - November 18, 2002.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
10/9/02	55.815	57.190	58.421	59.595	60.673	61.520	62.113	63.182	64.196
10/10/02	55.821	57.052	58.156	59.210	60.180	60.943	61.479	62.448	63.372
10/11/02	55.620	56.910	58.015	59.015	59.883	60.522	60.946	61.628	62.168
10/12/02	55.925	57.107	58.108	59.001	59.764	60.317	60.677	61.241	61.666
10/13/02	56.098	57.431	58.504	59.409	60.135	60.626	60.925	61.342	61.604
10/14/02	56.339	57.718	58.814	59.723	60.440	60.916	61.201	61.586	61.816
10/15/02	56.364	57.663	58.709	59.591	60.298	60.776	61.068	61.474	61.728
10/16/02	56.745	57.834	58.719	59.473	60.086	60.506	60.765	61.134	61.374
10/17/02	57.038	58.087	58.885	59.513	59.981	60.272	60.437	60.637	60.740
10/18/02	56.725	58.174	59.098	59.690	60.043	60.214	60.290	60.353	60.373
10/19/02	55.856	57.115	58.079	58.843	59.417	59.778	59.984	60.238	60.371
10/20/02	55.670	57.000	58.049	58.911	59.583	60.024	60.285	60.631	60.832
10/21/02	55.568	56.909	57.990	58.903	59.636	60.133	60.437	60.861	61.128
10/22/02	55.765	57.262	58.380	59.240	59.866	60.246	60.455	60.699	60.816
10/23/02	55.784	56.881	57.749	58.464	59.025	59.394	59.614	59.907	60.079
10/24/02	55.805	56.477	57.042	57.540	57.961	58.262	58.457	58.754	58.971
10/25/02	56.396	56.869	57.266	57.616	57.912	58.124	58.260	58.468	58.620
10/26/02	56.573	57.081	57.478	57.799	58.047	58.207	58.301	58.421	58.489
10/27/02	56.301	57.009	57.523	57.907	58.177	58.335	58.418	58.511	58.552
10/28/02	55.975	56.765	57.372	57.854	58.218	58.447	58.578	58.741	58.827
10/29/02	55.835	56.497	57.034	57.489	57.857	58.108	58.262	58.480	58.620
10/30/02	55.789	56.229	56.605	56.943	57.236	57.451	57.593	57.819	57.996
10/31/02	55.652	55.848	56.017	56.172	56.308	56.410	56.478	56.590	56.682
11/1/02	55.347	55.347	55.347	55.347	55.347	55.347	55.347	55.347	55.347
11/2/02	54.739	54.739	54.739	54.739	54.739	54.739	54.739	54.739	54.739
11/3/02	54.635	54.635	54.635	54.635	54.635	54.635	54.635	54.635	54.635
11/4/02	54.569	54.569	54.569	54.569	54.569	54.569	54.569	54.569	54.569
11/5/02	54.587	54.587	54.587	54.587	54.587	54.587	54.587	54.587	54.587
11/6/02	54.609	54.609	54.609	54.609	54.609	54.609	54.609	54.609	54.609
11/7/02	54.727	54.727	54.727	54.727	54.727	54.727	54.727	54.727	54.727
11/8/02	54.479	55.004	55.393	55.689	55.903	56.031	56.100	56.180	56.218
11/9/02	53.550	54.252	54.813	55.279	55.649	55.894	56.043	56.244	56.365
11/10/02	54.045	54.306	54.549	54.790	55.021	55.213	55.353	55.630	55.938
11/11/02	54.638	54.905	55.131	55.331	55.502	55.625	55.706	55.830	55.923
11/12/02	55.117	55.233	55.345	55.462	55.580	55.684	55.764	55.938	56.170
11/13/02	55.745	55.792	55.841	55.898	55.962	56.025	56.081	56.234	56.550
11/14/02	55.624	55.652	55.682	55.717	55.756	55.794	55.828	55.923	56.122
11/15/02	54.663	54.904	55.102	55.274	55.416	55.515	55.577	55.669	55.731
11/16/02	54.391	54.434	54.478	54.530	54.589	54.647	54.697	54.838	55.132
11/17/02	54.505	54.548	54.593	54.645	54.703	54.760	54.808	54.942	55.209
11/18/02	54.292	54.312	54.333	54.358	54.386	54.413	54.438	54.506	54.651

Table B-8. Average mean daily water temperature per model reach in November 19, 2002 - December 29, 2002.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
11/19/02	54.330	54.330	54.330	54.330	54.330	54.330	54.330	54.330	54.330
11/20/02	54.635	54.635	54.635	54.635	54.635	54.635	54.635	54.635	54.635
11/21/02	54.797	54.797	54.797	54.797	54.797	54.797	54.797	54.797	54.797
11/22/02	54.712	54.712	54.712	54.712	54.712	54.712	54.712	54.712	54.712
11/23/02	54.387	54.387	54.387	54.387	54.387	54.387	54.387	54.387	54.387
11/24/02	53.843	53.988	54.104	54.203	54.282	54.336	54.369	54.415	54.445
11/25/02	53.167	53.210	53.246	53.277	53.302	53.320	53.331	53.347	53.358
11/26/02	52.703	52.703	52.703	52.703	52.703	52.703	52.703	52.703	52.703
11/27/02	53.064	53.065	53.065	53.065	53.065	53.065	53.065	53.065	53.065
11/28/02	53.287	53.287	53.287	53.287	53.287	53.287	53.287	53.287	53.287
11/29/02	53.133	53.133	53.133	53.133	53.133	53.133	53.133	53.133	53.133
11/30/02	52.756	52.756	52.756	52.756	52.756	52.756	52.756	52.756	52.756
12/1/02	52.804	52.804	52.804	52.804	52.804	52.804	52.804	52.804	52.804
12/2/02	52.825	52.825	52.825	52.825	52.825	52.825	52.825	52.825	52.825
12/3/02	52.729	52.729	52.729	52.729	52.729	52.729	52.729	52.729	52.729
12/4/02	53.154	53.154	53.154	53.154	53.154	53.154	53.154	53.154	53.154
12/5/02	53.318	53.318	53.318	53.318	53.318	53.318	53.318	53.318	53.318
12/6/02	53.354	53.354	53.354	53.354	53.354	53.354	53.354	53.354	53.354
12/7/02	53.217	53.217	53.217	53.217	53.217	53.217	53.217	53.217	53.217
12/8/02	52.792	52.792	52.792	52.792	52.792	52.792	52.792	52.792	52.792
12/9/02	52.511	52.511	52.511	52.511	52.511	52.511	52.511	52.511	52.511
12/10/02	52.927	52.927	52.927	52.927	52.927	52.927	52.927	52.927	52.927
12/11/02	52.715	52.715	52.715	52.715	52.715	52.715	52.715	52.715	52.715
12/12/02	52.832	52.832	52.832	52.832	52.832	52.832	52.832	52.832	52.832
12/13/02	52.883	52.883	52.883	52.883	52.883	52.883	52.883	52.883	52.883
12/14/02	53.111	53.111	53.111	53.111	53.111	53.111	53.111	53.111	53.111
12/15/02	52.446	52.446	52.446	52.446	52.446	52.446	52.446	52.446	52.446
12/16/02	52.060	52.060	52.060	52.060	52.060	52.060	52.060	52.060	52.060
12/17/02	51.242	51.242	51.242	51.242	51.242	51.242	51.242	51.242	51.242
12/18/02	50.341	50.341	50.341	50.341	50.341	50.341	50.341	50.341	50.341
12/19/02	49.275	49.275	49.275	49.275	49.275	49.275	49.275	49.275	49.275
12/20/02	48.903	48.903	48.903	48.903	48.903	48.903	48.903	48.903	48.903
12/21/02	48.920	48.920	48.920	48.920	48.920	48.920	48.920	48.920	48.920
12/22/02	48.459	48.459	48.459	48.459	48.459	48.459	48.459	48.459	48.459
12/23/02	47.950	47.950	47.950	47.950	47.950	47.950	47.950	47.950	47.950
12/24/02	47.890	47.890	47.890	47.890	47.890	47.890	47.890	47.890	47.890
12/25/02	47.978	47.978	47.978	47.978	47.978	47.978	47.978	47.978	47.978
12/26/02	48.191	48.191	48.191	48.191	48.191	48.191	48.191	48.191	48.191
12/27/02	48.804	48.804	48.804	48.804	48.804	48.804	48.804	48.804	48.804
12/28/02	49.384	49.384	49.384	49.384	49.384	49.384	49.384	49.384	49.384
12/29/02	49.060	49.060	49.060	49.060	49.060	49.060	49.060	49.060	49.060

Table B-9. Average mean daily water temperature per model reach in December 30, 2002 - February 8, 2003.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
12/30/02	48.704	48.704	48.704	48.704	48.704	48.704	48.704	48.704	48.704
12/31/02	48.432	48.541	48.541	48.541	48.541	48.541	48.541	48.541	48.541
1/1/03	48.217	48.503	48.565	48.576	48.578	48.578	48.578	48.578	48.578
1/2/03	47.975	48.385	48.558	48.626	48.650	48.656	48.658	48.659	48.659
1/3/03	47.667	48.168	48.390	48.483	48.518	48.528	48.530	48.531	48.532
1/4/03	48.021	48.461	48.709	48.847	48.917	48.945	48.956	48.963	48.964
1/5/03	48.087	48.604	48.946	49.174	49.316	49.388	49.421	49.451	49.461
1/6/03	47.624	48.262	48.708	49.026	49.239	49.357	49.416	49.476	49.500
1/7/03	47.348	47.817	48.179	48.468	48.687	48.827	48.907	49.008	49.062
1/8/03	47.431	47.699	47.916	48.100	48.248	48.349	48.410	48.497	48.553
1/9/03	47.583	47.806	47.971	48.096	48.186	48.240	48.269	48.303	48.318
1/10/03	48.007	48.349	48.572	48.719	48.809	48.854	48.874	48.892	48.898
1/11/03	48.167	48.827	49.269	49.570	49.761	49.860	49.908	49.951	49.967
1/12/03	48.221	48.730	49.150	49.514	49.815	50.025	50.158	50.352	50.486
1/13/03	48.606	49.356	49.937	50.404	50.761	50.989	51.121	51.289	51.381
1/14/03	47.999	48.881	49.606	50.233	50.749	51.109	51.335	51.666	51.890
1/15/03	47.844	48.451	48.992	49.507	49.977	50.345	50.602	51.061	51.490
1/16/03	47.677	48.217	48.682	49.105	49.475	49.750	49.933	50.233	50.475
1/17/03	48.788	49.795	49.876	49.880	49.880	49.880	49.880	49.880	49.880
1/18/03	48.664	49.541	49.610	49.612	49.612	49.612	49.612	49.612	49.612
1/19/03	48.496	49.163	49.200	49.201	49.201	49.201	49.201	49.201	49.201
1/20/03	48.281	48.769	48.798	48.799	48.799	48.799	48.799	48.799	48.799
1/21/03	48.205	48.643	48.674	48.675	48.675	48.675	48.675	48.675	48.675
1/22/03	48.455	49.181	49.254	49.258	49.258	49.258	49.258	49.258	49.258
1/23/03	48.446	49.549	49.924	50.036	50.066	50.071	50.072	50.072	50.072
1/24/03	48.169	49.132	49.786	50.236	50.526	50.679	50.753	50.823	50.849
1/25/03	48.418	49.798	50.622	51.109	51.376	51.493	51.540	51.575	51.584
1/26/03	49.572	51.619	51.900	51.924	51.925	51.925	51.925	51.925	51.925
1/27/03	49.542	51.555	51.830	51.854	51.855	51.855	51.855	51.855	51.855
1/28/03	49.564	51.595	51.874	51.897	51.899	51.899	51.899	51.899	51.899
1/29/03	49.456	51.219	51.402	51.412	51.412	51.412	51.412	51.412	51.412
1/30/03	49.445	51.415	51.720	51.752	51.754	51.754	51.754	51.754	51.754
1/31/03	49.733	51.515	51.714	51.727	51.727	51.727	51.727	51.727	51.727
2/1/03	48.328	50.453	51.306	51.618	51.719	51.744	51.749	51.751	51.751
2/2/03	48.305	50.382	50.506	50.508	50.508	50.508	50.508	50.508	50.508
2/3/03	48.115	50.018	50.135	50.137	50.137	50.137	50.137	50.137	50.137
2/4/03	47.948	49.868	50.048	50.057	50.057	50.057	50.057	50.057	50.057
2/5/03	47.522	48.992	49.125	49.131	49.132	49.132	49.132	49.132	49.132
2/6/03	47.506	48.895	48.999	49.003	49.003	49.003	49.003	49.003	49.003
2/7/03	47.293	48.481	48.572	48.576	48.576	48.576	48.576	48.576	48.576
2/8/03	47.627	48.174	48.212	48.213	48.213	48.213	48.213	48.213	48.213

Table B-10. Average mean daily water temperature per model reach in February 9, 2003 - March 21, 2003.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
2/9/03	47.785	48.527	48.594	48.598	48.598	48.598	48.598	48.598	48.598
2/10/03	48.395	49.018	49.066	49.068	49.068	49.068	49.068	49.068	49.068
2/11/03	48.232	48.696	48.729	48.731	48.731	48.731	48.731	48.731	48.731
2/12/03	48.121	48.485	48.510	48.511	48.511	48.511	48.511	48.511	48.511
2/13/03	47.842	48.144	48.366	48.535	48.657	48.729	48.768	48.813	48.834
2/14/03	47.963	48.494	48.842	49.071	49.213	49.284	49.317	49.346	49.356
2/15/03	48.001	48.626	49.063	49.375	49.584	49.700	49.759	49.818	49.841
2/16/03	48.057	48.796	49.312	49.678	49.922	50.056	50.123	50.191	50.217
2/17/03	47.460	48.392	49.009	49.421	49.679	49.811	49.872	49.928	49.947
2/18/03	47.330	48.033	48.552	48.946	49.229	49.398	49.490	49.594	49.643
2/19/03	47.227	47.673	48.050	48.386	48.671	48.878	49.012	49.221	49.377
2/20/03	48.073	48.302	48.486	48.641	48.764	48.847	48.898	48.968	49.011
2/21/03	48.108	48.542	48.859	49.097	49.265	49.364	49.416	49.475	49.501
2/22/03	48.244	48.836	49.259	49.569	49.783	49.905	49.969	50.037	50.065
2/23/03	48.302	49.151	49.669	49.984	50.161	50.242	50.276	50.301	50.308
2/24/03	48.027	48.821	49.404	49.844	50.158	50.343	50.444	50.556	50.608
2/25/03	48.045	48.372	48.671	48.965	49.243	49.468	49.631	49.943	50.269
2/26/03	48.162	48.709	49.118	49.433	49.663	49.802	49.879	49.969	50.013
2/27/03	48.286	49.205	49.748	50.066	50.237	50.312	50.341	50.363	50.368
2/28/03	48.164	49.175	49.755	50.083	50.254	50.325	50.352	50.371	50.375
3/1/03	48.341	49.322	49.964	50.388	50.648	50.779	50.839	50.892	50.910
3/2/03	48.323	49.568	50.340	50.818	51.092	51.220	51.275	51.318	51.330
3/3/03	48.665	50.282	50.928	51.167	51.245	51.265	51.269	51.271	51.271
3/4/03	48.661	50.554	51.085	51.143	51.145	51.145	51.145	51.145	51.145
3/5/03	48.683	50.694	51.359	51.460	51.465	51.465	51.465	51.465	51.465
3/6/03	48.620	50.092	51.135	51.888	52.401	52.688	52.836	52.989	53.051
3/7/03	48.853	50.289	51.369	52.207	52.823	53.201	53.411	53.660	53.784
3/8/03	48.984	50.661	51.865	52.749	53.361	53.711	53.894	54.090	54.173
3/9/03	49.305	51.135	52.402	53.294	53.884	54.205	54.365	54.523	54.583
3/10/03	49.865	52.509	54.029	54.871	55.296	55.465	55.528	55.567	55.576
3/11/03	50.103	52.025	53.470	54.590	55.413	55.915	56.195	56.525	56.688
3/12/03	50.116	52.244	53.869	55.151	56.109	56.708	57.047	57.462	57.677
3/13/03	49.935	52.133	53.832	55.194	56.229	56.888	57.268	57.747	58.006
3/14/03	49.519	52.174	54.016	55.317	56.180	56.650	56.885	57.119	57.209
3/15/03	49.605	52.805	54.739	55.897	56.541	56.828	56.947	57.035	57.058
3/16/03	50.041	52.645	54.234	55.199	55.742	55.988	56.091	56.169	56.190
3/17/03	50.224	52.307	53.908	55.034	55.656	55.868	55.917	55.927	55.927
3/18/03	50.132	52.064	53.584	54.699	55.359	55.612	55.682	55.700	55.701
3/19/03	49.968	51.741	53.274	54.589	55.573	56.115	56.351	56.487	56.504
3/20/03	50.007	51.787	53.424	54.968	56.289	57.175	57.667	58.115	58.218
3/21/03	50.035	51.981	53.754	55.397	56.764	57.640	58.099	58.467	58.537

Table B-11. Average mean daily water temperature per model reach in March 22, 2003 - May 1, 2003.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
3/22/03	49.527	51.620	53.538	55.326	56.820	57.780	58.282	58.678	58.752
3/23/03	49.552	51.684	53.579	55.262	56.571	57.326	57.671	57.881	57.910
3/24/03	51.062	52.626	54.061	55.417	56.588	57.387	57.843	58.291	58.406
3/25/03	52.378	53.675	54.894	56.093	57.191	58.014	58.539	59.210	59.471
3/26/03	52.551	54.439	56.120	57.629	58.833	59.561	59.919	60.172	60.214
3/27/03	52.837	54.176	55.437	56.683	57.830	58.693	59.247	59.963	60.247
3/28/03	52.613	54.007	55.291	56.514	57.586	58.338	58.785	59.265	59.408
3/29/03	52.656	54.423	55.996	57.410	58.544	59.239	59.585	59.841	59.886
3/30/03	53.780	55.183	56.517	57.852	59.100	60.059	60.690	61.547	61.916
3/31/03	54.791	56.011	57.198	58.424	59.626	60.613	61.313	62.471	63.187
4/1/03	53.986	55.350	56.632	57.893	59.047	59.910	60.459	61.155	61.423
4/2/03	52.768	54.050	55.215	56.305	57.240	57.879	58.247	58.620	58.724
4/3/03	50.795	52.654	54.204	55.457	56.315	56.728	56.879	56.942	56.948
4/4/03	50.126	52.011	53.635	55.016	56.032	56.576	56.803	56.924	56.938
4/5/03	50.951	52.404	53.717	54.933	55.956	56.630	57.001	57.339	57.418
4/6/03	51.393	52.843	54.162	55.397	56.451	57.161	57.562	57.948	58.046
4/7/03	52.431	53.801	55.063	56.268	57.327	58.073	58.518	59.002	59.148
4/8/03	52.818	54.410	55.894	57.327	58.604	59.516	60.064	60.668	60.850
4/9/03	52.907	54.511	56.054	57.616	59.097	60.251	61.020	62.082	62.542
4/10/03	52.948	54.479	55.965	57.489	58.963	60.143	60.954	62.170	62.779
4/11/03	52.948	54.572	56.092	57.569	58.894	59.850	60.431	61.085	61.290
4/12/03	51.765	53.409	54.949	56.449	57.795	58.765	59.354	60.013	60.215
4/13/03	52.233	53.126	53.978	54.839	55.662	56.318	56.772	57.483	57.892
4/14/03	53.584	54.509	55.291	55.955	56.459	56.751	56.892	56.995	57.014
4/15/03	53.023	54.510	55.738	56.729	57.416	57.757	57.890	57.954	57.961
4/16/03	52.893	54.356	55.656	56.830	57.784	58.384	58.696	58.951	59.003
4/17/03	52.272	54.212	55.888	57.321	58.385	58.962	59.208	59.343	59.359
4/18/03	52.483	54.595	56.424	57.988	59.145	59.765	60.024	60.159	60.174
4/19/03	53.217	55.204	56.951	58.486	59.672	60.354	60.667	60.863	60.890
4/20/03	54.480	55.799	57.021	58.196	59.242	59.995	60.454	60.986	61.163
4/21/03	54.453	55.604	56.662	57.674	58.571	59.214	59.606	60.065	60.222
4/22/03	54.224	55.496	56.610	57.600	58.393	58.884	59.136	59.340	59.381
4/23/03	52.675	54.643	56.333	57.765	58.813	59.369	59.600	59.719	59.733
4/24/03	51.064	53.209	55.067	56.653	57.820	58.438	58.692	58.820	58.834
4/25/03	50.084	51.967	53.530	54.781	55.625	56.020	56.160	56.215	56.220
4/26/03	50.267	52.503	54.118	55.131	55.596	55.711	55.728	55.730	55.730
4/27/03	51.158	53.536	55.224	56.249	56.693	56.792	56.805	56.806	56.806
4/28/03	51.358	53.215	54.735	55.927	56.710	57.062	57.181	57.225	57.228
4/29/03	51.094	52.778	54.134	55.178	55.847	56.139	56.235	56.268	56.271
4/30/03	51.365	53.650	55.216	56.113	56.471	56.541	56.549	56.549	56.549
5/1/03	51.322	53.987	55.928	57.146	57.694	57.823	57.840	57.841	57.841

Table B-12. Average mean daily water temperature per model reach in May 2, 2003 - June 11, 2003.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
5/2/03	51.202	53.229	54.904	56.232	57.111	57.510	57.645	57.694	57.697
5/3/03	51.056	53.103	54.749	55.998	56.773	57.089	57.182	57.209	57.211
5/4/03	51.602	53.990	55.752	56.896	57.446	57.593	57.617	57.620	57.620
5/5/03	52.343	55.057	57.007	58.201	58.719	58.833	58.847	58.848	58.848
5/6/03	51.857	54.692	56.882	58.395	59.184	59.420	59.464	59.469	59.470
5/7/03	51.832	54.336	56.370	57.918	58.866	59.239	59.341	59.368	59.369
5/8/03	51.173	54.023	56.220	57.731	58.510	58.738	58.779	58.784	58.784
5/9/03	52.048	56.572	58.031	58.225	58.234	58.234	58.234	58.234	58.234
5/10/03	51.701	56.963	58.969	59.377	59.417	59.418	59.418	59.418	59.418
5/11/03	51.761	56.914	59.427	60.154	60.255	60.259	60.259	60.259	60.259
5/12/03	52.291	57.322	60.002	60.930	61.103	61.113	61.114	61.114	61.114
5/13/03	51.834	57.120	60.552	62.147	62.560	62.595	62.596	62.596	62.596
5/14/03	51.723	56.688	60.361	62.565	63.432	63.585	63.598	63.599	63.599
5/15/03	51.511	56.744	59.948	61.773	62.696	63.059	63.191	63.273	63.290
5/16/03	52.352	56.977	60.353	62.337	63.087	63.208	63.216	63.216	63.217
5/17/03	52.761	57.631	61.084	62.988	63.631	63.715	63.719	63.719	63.719
5/18/03	53.177	57.353	60.143	61.753	62.482	62.701	62.756	62.775	62.777
5/19/03	53.386	57.735	60.357	61.689	62.224	62.368	62.402	62.413	62.414
5/20/03	53.248	57.926	60.681	62.094	62.697	62.882	62.934	62.956	62.959
5/21/03	53.541	57.979	60.824	62.494	63.340	63.663	63.776	63.840	63.852
5/22/03	54.065	58.331	61.074	62.837	63.891	64.403	64.631	64.822	64.881
5/23/03	55.324	58.652	61.040	62.792	64.004	64.696	65.057	65.443	65.606
5/24/03	56.012	58.333	60.179	61.710	62.919	63.721	64.202	64.852	65.241
5/25/03	55.619	58.992	61.073	62.349	63.076	63.408	63.550	63.659	63.689
5/26/03	55.918	59.477	61.963	63.398	63.968	64.080	64.092	64.093	64.093
5/27/03	56.207	59.940	62.737	64.532	65.349	65.539	65.563	65.565	65.565
5/28/03	56.571	60.166	63.037	65.111	66.254	66.624	66.699	66.711	66.711
5/29/03	56.144	58.869	61.286	63.410	65.031	65.931	66.322	66.537	66.563
5/30/03	55.846	58.684	60.950	62.623	63.600	63.955	64.044	64.063	64.064
5/31/03	56.457	59.856	62.275	63.709	64.292	64.406	64.417	64.418	64.418
6/1/03	56.911	60.767	63.542	65.194	65.859	65.984	65.996	65.996	65.996
6/2/03	56.847	60.809	63.887	65.976	67.002	67.268	67.307	67.310	67.310
6/3/03	56.715	60.298	63.322	65.722	67.250	67.870	68.041	68.083	68.085
6/4/03	56.698	59.856	62.580	64.849	66.423	67.167	67.423	67.515	67.522
6/5/03	56.398	59.724	62.507	64.697	66.083	66.644	66.800	66.840	66.841
6/6/03	56.347	59.496	62.168	64.331	65.767	66.400	66.599	66.660	66.664
6/7/03	56.684	59.916	62.596	64.676	65.971	66.483	66.622	66.655	66.657
6/8/03	57.228	60.481	63.157	65.208	66.459	66.939	67.063	67.091	67.092
6/9/03	56.873	60.616	63.595	65.721	66.860	67.205	67.269	67.277	67.277
6/10/03	57.119	60.491	63.190	65.159	66.265	66.634	66.712	66.725	66.726
6/11/03	57.284	60.809	63.530	65.383	66.312	66.567	66.608	66.613	66.613

Table B-13. Average mean daily water temperature per model reach in June 12, 2003 - July 22, 2003.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
6/12/03	57.427	60.699	63.321	65.243	66.337	66.711	66.793	66.808	66.808
6/13/03	57.438	60.708	63.328	65.247	66.338	66.711	66.793	66.808	66.808
6/14/03	57.725	60.934	63.486	65.336	66.373	66.720	66.795	66.808	66.808
6/15/03	58.021	61.333	64.002	65.978	67.117	67.516	67.607	67.624	67.624
6/16/03	57.996	61.418	64.261	66.470	67.842	68.380	68.524	68.558	68.559
6/17/03	57.946	61.177	64.003	66.413	68.145	69.010	69.332	69.462	69.473
6/18/03	57.852	60.873	63.499	65.724	67.317	68.113	68.410	68.533	68.544
6/19/03	58.223	61.132	63.577	65.542	66.846	67.425	67.611	67.672	67.676
6/20/03	58.149	61.443	64.091	66.045	67.167	67.557	67.646	67.662	67.662
6/21/03	57.856	61.531	64.425	66.460	67.529	67.845	67.901	67.908	67.908
6/22/03	57.752	61.511	64.590	66.901	68.247	68.716	68.821	68.839	68.840
6/23/03	57.825	61.630	64.774	67.169	68.593	69.107	69.227	69.250	69.251
6/24/03	58.623	62.364	65.377	67.579	68.811	69.214	69.296	69.309	69.309
6/25/03	58.590	62.857	66.206	68.509	69.658	69.961	70.006	70.010	70.010
6/26/03	58.453	63.528	66.751	68.803	70.020	70.604	70.863	71.077	71.141
6/27/03	59.023	62.599	65.737	68.410	70.315	71.246	71.580	71.705	71.715
6/28/03	59.527	62.161	64.547	66.728	68.494	69.571	70.099	70.461	70.517
6/29/03	59.567	61.817	63.817	65.601	67.008	67.843	68.241	68.506	68.547
6/30/03	59.790	62.106	64.065	65.679	66.812	67.374	67.587	67.681	67.690
7/1/03	57.996	60.981	63.121	64.691	65.777	66.397	66.721	67.066	67.213
7/2/03	57.825	60.132	61.941	63.415	64.558	65.300	65.737	66.307	66.631
7/3/03	57.985	59.623	61.006	62.237	63.285	64.043	64.535	65.301	65.874
7/4/03	58.706	60.416	61.770	62.887	63.764	64.342	64.686	65.146	65.417
7/5/03	59.035	60.867	62.294	63.448	64.334	64.904	65.236	65.663	65.900
7/6/03	59.030	60.962	62.448	63.632	64.528	65.094	65.419	65.825	66.041
7/7/03	59.438	60.944	62.180	63.242	64.114	64.719	65.097	65.645	66.012
7/8/03	59.497	61.138	62.409	63.431	64.211	64.710	64.999	65.365	65.566
7/9/03	60.932	61.834	62.644	63.419	64.133	64.696	65.093	65.812	66.503
7/10/03	61.139	63.292	64.519	65.208	65.563	65.709	65.765	65.802	65.811
7/11/03	59.524	63.134	64.955	65.839	66.231	66.365	66.409	66.432	66.436
7/12/03	59.213	62.356	64.344	65.605	66.349	66.704	66.861	66.990	67.028
7/13/03	59.288	62.049	63.861	65.060	65.802	66.176	66.349	66.502	66.552
7/14/03	59.767	62.147	63.746	64.833	65.525	65.885	66.057	66.217	66.273
7/15/03	60.380	62.590	64.013	64.934	65.489	65.761	65.884	65.988	66.021
7/16/03	60.306	63.020	64.531	65.357	65.771	65.936	65.997	66.035	66.044
7/17/03	58.683	62.337	64.497	65.760	66.444	66.740	66.859	66.944	66.965
7/18/03	58.534	61.564	63.710	65.264	66.324	66.919	67.225	67.543	67.674
7/19/03	58.642	61.167	63.081	64.580	65.693	66.381	66.769	67.236	67.473
7/20/03	58.406	61.266	63.301	64.780	65.793	66.365	66.661	66.971	67.100
7/21/03	59.374	61.550	63.226	64.564	65.578	66.220	66.589	67.051	67.299
7/22/03	60.370	62.300	63.739	64.847	65.652	66.140	66.408	66.721	66.872

Table B-14. Average mean daily water temperature per model reach in July 23, 2003 - September 1, 2003.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
7/23/03	60.518	63.060	64.554	65.424	65.892	66.093	66.174	66.230	66.244
7/24/03	59.033	62.521	64.561	65.740	66.370	66.638	66.745	66.819	66.837
7/25/03	58.972	61.693	63.616	65.004	65.947	66.475	66.745	67.025	67.139
7/26/03	58.699	61.716	63.718	65.062	65.904	66.336	66.539	66.723	66.785
7/27/03	58.462	61.609	63.747	65.218	66.169	66.671	66.915	67.146	67.230
7/28/03	58.653	61.397	63.407	64.921	65.997	66.632	66.973	67.355	67.529
7/29/03	59.237	61.217	62.815	64.162	65.246	65.979	66.428	67.054	67.450
7/30/03	59.669	61.274	62.599	63.749	64.701	65.367	65.788	66.408	66.835
7/31/03	59.532	61.367	62.784	63.918	64.781	65.329	65.645	66.043	66.259
8/1/03	58.260	60.922	62.806	64.168	65.095	65.615	65.882	66.160	66.273
8/2/03	58.404	59.980	61.295	62.449	63.418	64.106	64.547	65.213	65.689
8/3/03	58.846	60.592	61.884	62.870	63.580	64.004	64.236	64.501	64.626
8/4/03	59.089	60.932	62.294	63.331	64.076	64.521	64.763	65.040	65.169
8/5/03	59.825	61.310	62.456	63.373	64.070	64.514	64.769	65.091	65.264
8/6/03	60.664	61.965	62.983	63.812	64.454	64.870	65.115	65.434	65.614
8/7/03	60.563	62.313	63.541	64.420	65.011	65.339	65.505	65.674	65.742
8/8/03	58.574	61.758	63.739	64.970	65.681	66.012	66.155	66.267	66.300
8/9/03	58.896	61.743	63.738	65.164	66.122	66.652	66.920	67.193	67.301
8/10/03	59.049	61.930	63.957	65.412	66.395	66.941	67.219	67.504	67.619
8/11/03	59.622	62.408	64.367	65.774	66.723	67.251	67.520	67.795	67.906
8/12/03	60.250	62.646	64.404	65.731	66.676	67.234	67.536	67.874	68.029
8/13/03	57.689	61.023	63.375	65.068	66.214	66.854	67.182	67.518	67.654
8/14/03	55.521	59.640	62.485	64.485	65.804	66.519	66.875	67.224	67.358
8/15/03	55.370	58.952	61.588	63.582	65.008	65.853	66.311	66.828	67.066
8/16/03	55.464	58.866	61.401	63.349	64.765	65.621	66.092	66.640	66.903
8/17/03	55.531	58.616	60.990	62.885	64.320	65.228	65.750	66.403	66.752
8/18/03	56.063	58.684	60.753	62.453	63.781	64.653	65.171	65.857	66.257
8/19/03	56.701	58.880	60.639	62.124	63.318	64.127	64.622	65.314	65.751
8/20/03	56.696	58.851	60.562	61.977	63.092	63.829	64.270	64.863	65.215
8/21/03	57.019	58.728	60.154	61.405	62.454	63.200	63.676	64.395	64.909
8/22/03	57.218	58.291	59.256	60.180	61.033	61.707	62.182	63.045	63.879
8/23/03	58.262	59.129	59.896	60.615	61.265	61.765	62.110	62.709	63.247
8/24/03	58.793	60.065	61.107	62.003	62.736	63.244	63.562	64.020	64.327
8/25/03	59.106	60.623	61.847	62.881	63.713	64.277	64.622	65.104	65.409
8/26/03	59.452	60.825	62.007	63.084	64.026	64.725	65.191	65.952	66.568
8/27/03	59.414	60.910	62.174	63.299	64.258	64.951	65.401	66.102	66.627
8/28/03	56.690	59.764	61.998	63.664	64.835	65.518	65.881	66.280	66.457
8/29/03	56.443	59.292	61.468	63.187	64.476	65.282	65.740	66.302	66.595
8/30/03	55.475	58.686	61.132	63.059	64.498	65.396	65.904	66.524	66.844
8/31/03	54.297	57.864	60.576	62.708	64.296	65.284	65.841	66.519	66.867
9/1/03	54.940	57.824	60.148	62.105	63.677	64.739	65.388	66.290	66.857

Table B-15. Average mean daily water temperature per model reach in September 2, 2003 - October 12, 2003.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
9/2/03	55.112	57.997	60.326	62.291	63.872	64.943	65.598	66.513	67.091
9/3/03	55.529	57.451	59.165	60.791	62.276	63.436	64.245	65.685	67.028
9/4/03	54.255	56.674	58.698	60.479	61.980	63.049	63.736	64.780	65.535
9/5/03	54.150	56.662	58.698	60.424	61.819	62.770	63.355	64.179	64.708
9/6/03	52.799	56.004	58.438	60.349	61.771	62.653	63.151	63.755	64.064
9/7/03	52.232	55.404	57.814	59.710	61.123	62.001	62.497	63.101	63.410
9/8/03	52.367	55.087	57.244	59.028	60.431	61.358	61.912	62.655	63.097
9/9/03	52.797	54.688	56.328	57.832	59.158	60.152	60.821	61.930	62.852
9/10/03	53.373	54.984	56.410	57.754	58.971	59.913	60.565	61.706	62.742
9/11/03	53.063	55.236	57.016	58.544	59.797	60.664	61.205	61.988	62.510
9/12/03	53.545	55.652	57.422	58.986	60.311	61.260	61.872	62.812	63.501
9/13/03	54.526	56.315	57.864	59.283	60.532	61.466	62.093	63.130	63.987
9/14/03	54.859	56.737	58.346	59.803	61.068	62.001	62.619	63.616	64.406
9/15/03	55.147	56.940	58.454	59.801	60.948	61.777	62.314	63.150	63.775
9/16/03	54.968	56.885	58.526	60.010	61.296	62.243	62.869	63.876	64.670
9/17/03	55.195	57.217	58.890	60.343	61.550	62.398	62.933	63.727	64.277
9/18/03	53.428	56.511	58.784	60.507	61.742	62.476	62.875	63.326	63.536
9/19/03	52.890	56.339	58.824	60.658	61.934	62.668	63.054	63.470	63.650
9/20/03	52.958	56.519	59.279	61.498	63.192	64.275	64.902	65.699	66.135
9/21/03	53.437	56.862	59.591	61.860	63.655	64.849	65.568	66.541	67.129
9/22/03	53.719	57.248	60.069	62.423	64.294	65.544	66.300	67.332	67.962
9/23/03	53.426	56.893	59.710	62.106	64.049	65.377	66.197	67.360	68.112
9/24/03	53.073	56.208	58.846	61.186	63.173	64.602	65.526	66.954	68.011
9/25/03	53.422	56.359	58.827	61.012	62.861	64.189	65.045	66.363	67.331
9/26/03	53.227	56.350	58.915	61.125	62.942	64.205	64.995	66.146	66.922
9/27/03	53.308	56.403	58.949	61.147	62.958	64.218	65.009	66.165	66.948
9/28/03	53.461	56.428	58.895	61.049	62.849	64.120	64.928	66.139	66.993
9/29/03	53.256	56.083	58.446	60.522	62.267	63.509	64.304	65.510	66.377
9/30/03	53.046	56.212	58.809	61.043	62.877	64.148	64.943	66.096	66.870
10/1/03	53.011	56.038	58.521	60.657	62.411	63.627	64.388	65.492	66.232
10/2/03	52.988	55.886	58.269	60.323	62.016	63.193	63.931	65.009	65.738
10/3/03	52.977	55.792	58.087	60.047	61.644	62.741	63.422	64.396	65.035
10/4/03	53.236	56.041	58.319	60.255	61.826	62.899	63.561	64.500	65.108
10/5/03	53.509	56.590	59.022	61.021	62.583	63.607	64.216	65.022	65.492
10/6/03	53.335	56.519	59.050	61.150	62.806	63.905	64.565	65.454	65.987
10/7/03	53.579	56.492	58.886	60.949	62.646	63.825	64.564	65.640	66.367
10/8/03	53.660	56.313	58.542	60.514	62.183	63.380	64.152	65.339	66.211
10/9/03	53.815	56.244	58.281	60.079	61.597	62.683	63.381	64.450	65.228
10/10/03	53.584	55.645	57.349	58.827	60.052	60.910	61.452	62.252	62.804
10/11/03	52.761	54.969	56.735	58.209	59.382	60.166	60.640	61.289	61.685
10/12/03	52.063	54.597	56.585	58.207	59.466	60.284	60.766	61.397	61.757

Table B-16. Average mean daily water temperature per model reach in October 13, 2003 - November 22, 2003.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
10/13/03	51.591	53.973	55.871	57.448	58.696	59.527	60.026	60.703	61.111
10/14/03	51.444	53.773	55.647	57.225	58.490	59.344	59.865	60.588	61.041
10/15/03	51.415	53.566	55.330	56.846	58.090	58.951	59.489	60.268	60.790
10/16/03	51.668	53.669	55.327	56.772	57.973	58.819	59.355	60.152	60.709
10/17/03	51.731	53.701	55.352	56.806	58.033	58.910	59.473	60.333	60.956
10/18/03	51.913	53.819	55.418	56.829	58.021	58.874	59.423	60.264	60.877
10/19/03	52.122	53.853	55.328	56.656	57.801	58.640	59.191	60.070	60.752
10/20/03	52.275	54.358	56.028	57.425	58.540	59.287	59.741	60.364	60.748
10/21/03	52.259	54.342	56.042	57.496	58.682	59.498	60.005	60.732	61.211
10/22/03	52.231	54.173	55.795	57.220	58.416	59.267	59.811	60.636	61.227
10/23/03	52.440	54.463	56.091	57.462	58.562	59.304	59.757	60.387	60.781
10/24/03	52.152	54.112	55.685	57.004	58.058	58.766	59.196	59.789	60.156
10/25/03	52.599	54.540	56.062	57.305	58.268	58.894	59.263	59.745	60.020
10/26/03	53.084	54.978	56.457	57.657	58.582	59.179	59.529	59.981	60.235
10/27/03	52.906	55.073	56.700	57.961	58.885	59.449	59.762	60.132	60.315
10/28/03	52.715	54.837	56.450	57.719	58.665	59.254	59.586	59.991	60.199
10/29/03	53.281	55.129	56.561	57.713	58.593	59.155	59.481	59.895	60.122
10/30/03	52.734	54.186	55.353	56.331	57.112	57.637	57.956	58.396	58.669
10/31/03	52.520	53.577	54.415	55.108	55.653	56.013	56.228	56.517	56.688
11/1/03	51.965	52.930	53.643	54.186	54.576	54.809	54.936	55.081	55.148
11/2/03	51.546	52.097	52.555	52.957	53.293	53.531	53.683	53.912	54.075
11/3/03	51.836	51.930	52.028	52.140	52.267	52.391	52.498	52.791	53.380
11/4/03	52.363	52.369	52.376	52.384	52.394	52.403	52.411	52.434	52.483
11/5/03	53.627	53.603	53.577	53.546	53.511	53.476	53.445	53.356	53.162
11/6/03	52.877	52.908	52.940	52.978	53.021	53.064	53.101	53.206	53.431
11/7/03	52.034	52.804	53.350	53.745	54.014	54.165	54.243	54.324	54.357
11/8/03	52.163	53.012	53.651	54.147	54.511	54.733	54.857	55.004	55.077
11/9/03	52.230	53.058	53.717	54.264	54.696	54.983	55.155	55.387	55.527
11/10/03	51.899	52.761	53.455	54.039	54.507	54.822	55.015	55.282	55.449
11/11/03	52.039	52.564	53.028	53.465	53.861	54.166	54.377	54.745	55.078
11/12/03	52.376	52.748	53.084	53.408	53.709	53.949	54.119	54.432	54.740
11/13/03	52.646	52.847	53.045	53.256	53.475	53.672	53.828	54.188	54.712
11/14/03	52.433	52.682	52.919	53.163	53.405	53.614	53.773	54.110	54.534
11/15/03	51.955	52.245	52.507	52.758	52.992	53.176	53.307	53.547	53.781
11/16/03	52.171	52.348	52.507	52.659	52.799	52.909	52.987	53.128	53.262
11/17/03	52.743	52.900	53.038	53.166	53.281	53.368	53.428	53.530	53.618
11/18/03	52.178	52.541	52.817	53.032	53.192	53.291	53.347	53.414	53.448
11/19/03	51.862	52.479	52.904	53.201	53.396	53.502	53.554	53.605	53.624
11/20/03	51.301	52.153	52.758	53.198	53.499	53.669	53.756	53.848	53.886
11/21/03	50.824	51.334	51.754	52.118	52.418	52.628	52.760	52.953	53.085
11/22/03	50.578	50.662	50.736	50.804	50.865	50.910	50.941	50.994	51.039

Table B-17. Average mean daily water temperature per model reach in November 23, 2003 - January 2, 2004.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
11/23/03	50.215	50.215	50.215	50.215	50.215	50.215	50.215	50.215	50.215
11/24/03	50.284	50.263	50.241	50.216	50.186	50.156	50.130	50.055	49.890
11/25/03	50.419	50.349	50.274	50.186	50.084	49.981	49.891	49.630	49.047
11/26/03	50.786	50.681	50.569	50.439	50.289	50.138	50.006	49.626	48.791
11/27/03	50.796	50.683	50.563	50.422	50.261	50.100	49.958	49.553	48.669
11/28/03	50.819	50.712	50.599	50.466	50.315	50.162	50.029	49.647	48.813
11/29/03	50.567	50.531	50.493	50.448	50.397	50.345	50.301	50.172	49.895
11/30/03	50.649	50.619	50.587	50.549	50.506	50.463	50.426	50.318	50.086
12/1/03	50.941	50.921	50.900	50.875	50.847	50.819	50.794	50.724	50.571
12/2/03	51.421	51.431	51.442	51.454	51.469	51.483	51.496	51.531	51.608
12/3/03	51.488	51.559	51.634	51.721	51.821	51.921	52.008	52.255	52.786
12/4/03	51.203	51.293	51.388	51.499	51.625	51.751	51.861	52.173	52.842
12/5/03	51.307	51.385	51.469	51.566	51.677	51.788	51.885	52.159	52.748
12/6/03	51.437	51.534	51.637	51.757	51.894	52.030	52.149	52.486	53.209
12/7/03	51.511	51.616	51.726	51.855	52.003	52.149	52.278	52.641	53.418
12/8/03	51.010	51.074	51.141	51.220	51.310	51.400	51.478	51.700	52.179
12/9/03	50.559	50.576	50.594	50.615	50.639	50.663	50.685	50.745	50.875
12/10/03	50.159	50.193	50.228	50.270	50.318	50.365	50.407	50.525	50.780
12/11/03	50.016	50.067	50.122	50.185	50.257	50.329	50.392	50.571	50.957
12/12/03	49.865	49.892	49.920	49.953	49.991	50.028	50.061	50.155	50.356
12/13/03	49.914	49.932	49.952	49.975	50.001	50.027	50.049	50.114	50.254
12/14/03	50.078	50.120	50.165	50.218	50.278	50.338	50.390	50.539	50.860
12/15/03	49.588	49.615	49.644	49.677	49.715	49.753	49.786	49.880	50.083
12/16/03	48.828	48.841	48.854	48.870	48.887	48.905	48.921	48.965	49.061
12/17/03	48.515	48.505	48.494	48.481	48.466	48.451	48.438	48.400	48.320
12/18/03	48.431	48.408	48.383	48.355	48.322	48.289	48.261	48.179	48.002
12/19/03	48.438	48.426	48.414	48.399	48.381	48.364	48.349	48.307	48.214
12/20/03	48.612	48.626	48.641	48.658	48.678	48.698	48.716	48.766	48.873
12/21/03	48.703	48.756	48.813	48.879	48.954	49.029	49.095	49.282	49.685
12/22/03	48.427	48.497	48.572	48.658	48.757	48.855	48.941	49.185	49.711
12/23/03	48.418	48.490	48.566	48.656	48.757	48.859	48.947	49.199	49.739
12/24/03	48.545	48.633	48.726	48.834	48.958	49.081	49.189	49.495	50.151
12/25/03	47.876	48.516	48.991	49.352	49.610	49.763	49.846	49.939	49.981
12/26/03	47.368	47.735	48.037	48.296	48.509	48.657	48.749	48.882	48.971
12/27/03	47.244	47.352	47.426	47.477	47.510	47.527	47.536	47.544	47.547
12/28/03	46.914	46.897	46.880	46.859	46.836	46.812	46.792	46.733	46.605
12/29/03	46.620	46.586	46.550	46.508	46.460	46.412	46.369	46.247	45.980
12/30/03	46.901	46.873	46.844	46.810	46.770	46.731	46.696	46.597	46.381
12/31/03	47.245	47.250	47.256	47.263	47.271	47.279	47.286	47.306	47.348
1/1/04	47.488	47.509	47.530	47.556	47.585	47.614	47.639	47.710	47.862
1/2/04	46.944	46.978	47.013	47.055	47.102	47.149	47.190	47.307	47.554

Table B-18. Average mean daily water temperature per model reach in January 3, 2004 - February 10, 2004.

DATE	Reach 1 (RM 65-67.3)	Reach 2 (RM 62-65)	Reach 3 (RM 59-62)	Reach 4 (RM 55-59)	Reach 5 (RM 51-55)	Reach 6 (RM 47-51)	Reach 7 (RM 44-47)	Reach 8 (RM 27.7-44)	Reach 9 (RM 0-27.7)
1/3/04	46.755	46.744	46.731	46.717	46.700	46.683	46.669	46.627	46.537
1/4/04	46.822	46.762	46.699	46.624	46.539	46.454	46.380	46.168	45.708
1/5/04	46.860	46.789	46.713	46.625	46.523	46.422	46.333	46.080	45.531
1/6/04	46.864	46.812	46.756	46.691	46.617	46.543	46.478	46.292	45.890
1/7/04	46.975	46.945	46.912	46.874	46.831	46.788	46.750	46.642	46.409
1/8/04	47.359	47.366	47.374	47.383	47.393	47.403	47.411	47.436	47.490
1/9/04	47.218	47.265	47.314	47.372	47.438	47.504	47.562	47.727	48.081
1/10/04	47.705	47.772	47.843	47.925	48.019	48.114	48.196	48.429	48.932
1/11/04	47.647	47.764	47.888	48.032	48.197	48.361	48.504	48.910	49.778
1/12/04	47.847	47.954	48.068	48.201	48.352	48.503	48.635	49.008	49.807
1/13/04	47.160	47.305	47.458	47.636	47.839	48.042	48.218	48.718	49.786
1/14/04	47.026	47.149	47.280	47.431	47.605	47.777	47.928	48.355	49.270
1/15/04	46.845	46.958	47.078	47.218	47.377	47.536	47.674	48.067	48.910
1/16/04	46.962	47.069	47.184	47.317	47.469	47.620	47.753	48.128	48.933
1/17/04	46.924	47.019	47.121	47.240	47.375	47.510	47.628	47.963	48.682
1/18/04	47.191	47.296	47.409	47.539	47.688	47.837	47.967	48.335	49.125
1/19/04	46.995	47.101	47.214	47.345	47.495	47.644	47.775	48.145	48.938
1/20/04	47.242	47.357	47.480	47.623	47.786	47.949	48.091	48.493	49.355
1/21/04	47.094	47.212	47.336	47.482	47.648	47.813	47.958	48.367	49.243
1/22/04	46.836	46.945	47.061	47.195	47.349	47.502	47.636	48.016	48.830
1/23/04	46.760	46.849	46.943	47.053	47.178	47.303	47.412	47.722	48.387
1/24/04	46.989	47.086	47.189	47.309	47.446	47.582	47.702	48.040	48.767
1/25/04	46.746	46.855	46.970	47.104	47.258	47.411	47.544	47.923	48.736
1/26/04	46.376	46.463	46.555	46.662	46.784	46.907	47.013	47.317	47.969
1/27/04	46.323	46.418	46.519	46.636	46.770	46.905	47.022	47.354	48.068
1/28/04	45.703	45.834	45.974	46.137	46.323	46.508	46.670	47.129	48.113
1/29/04	45.507	45.620	45.741	45.881	46.041	46.200	46.340	46.735	47.585
1/30/04	45.914	45.994	46.079	46.179	46.292	46.405	46.504	46.785	47.390
1/31/04	45.900	45.990	46.085	46.197	46.324	46.451	46.562	46.877	47.554
2/1/04	46.123	46.198	46.278	46.371	46.478	46.584	46.677	46.941	47.510
2/2/04	46.076	46.168	46.266	46.379	46.509	46.639	46.752	47.074	47.765
2/3/04	45.893	45.981	46.075	46.184	46.308	46.432	46.541	46.849	47.512
2/4/04	46.191	46.271	46.356	46.455	46.568	46.681	46.780	47.060	47.663
2/5/04	46.562	46.639	46.722	46.818	46.928	47.038	47.134	47.406	47.991
2/6/04	46.542	46.653	46.770	46.907	47.063	47.219	47.355	47.741	48.569
2/7/04	46.772	46.880	46.996	47.130	47.283	47.436	47.570	47.948	48.761
2/8/04	46.889	46.984	47.085	47.202	47.336	47.470	47.586	47.918	48.629
2/9/04	46.924	47.020	47.122	47.240	47.375	47.510	47.628	47.962	48.680
2/10/04	46.406	46.487	46.574	46.675	46.791	46.906	47.007	47.293	47.908